

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.

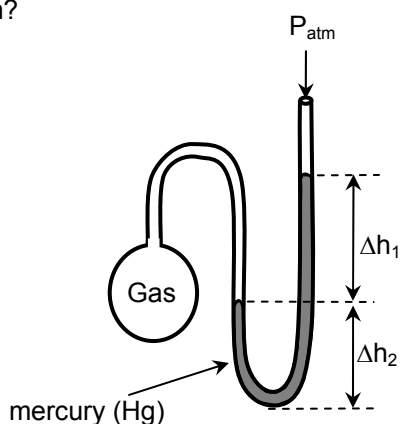
- 1 The "lead" of a pencil is mostly
- lead, Pb
  - carbon, C
  - silicon dioxide, SiO<sub>2</sub>
  - silicon, Si
  - calcium carbonate, CaCO<sub>3</sub>
- 2 How many protons, neutrons and electrons are there in a single atom of  $^{209}_{84}\text{Po}$ ?
- 84 protons, 84 neutrons, 209 electrons
  - 84 protons, 209 neutrons, 84 electrons
  - 209 protons, 125 neutrons, 209 electrons
  - 125 protons, 84 neutrons, 125 electrons
  - 84 protons, 125 neutrons, 84 electrons
- 3 The mass of one atom of  $^{12}\text{C}$  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.)
- $2.2 \times 10^{27}$
  - $4.5 \times 10^{28}$
  - $8.0 \times 10^{21}$
  - $3.8 \times 10^{23}$
  - $8.0 \times 10^{24}$
- 4 Mercury, Hg(l), has a density of  $13.6 \text{ g mL}^{-1}$  at  $25^\circ\text{C}$ . What is the volume of 4.25 grams of Hg(l) at  $25^\circ\text{C}$ ?
- 0.0173 mL
  - 3.20 mL
  - 0.0562 mL
  - 0.313 mL
  - 0.0735 mL
- 5 Which of the following molecules has the same number of electrons as a water molecule?
- HF
  - BH<sub>3</sub>
  - CO
  - H<sub>2</sub>S
  - F<sub>2</sub>
- 6 Which of the following elements is a liquid at room temperature and atmospheric pressure?
- chlorine
  - phosphorus
  - sulfur
  - bromine
  - iodine
- 7 What is the formula of the binary compound formed between Mg and P?
- MgP
  - Mg<sub>2</sub>P
  - MgP<sub>2</sub>
  - Mg<sub>2</sub>P<sub>3</sub>
  - Mg<sub>3</sub>P<sub>2</sub>
- 8 Which of the following elements has no known stable compounds?
- neon, Ne
  - xenon, Xe
  - gold, Au
  - platinum, Pt
  - uranium, U
- 9 Which of the following elements is believed to be the most abundant in the earth's crust?
- hydrogen
  - oxygen
  - carbon
  - nitrogen
  - 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  $\text{Cl}^-$   
 B  $\text{Cl}^+$   
 C  $\text{Cl}_2$   
 D  $\text{H}_2$   
 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  $^{42}_{20}\text{Ca}$ ?
- A  $^{42}_{22}\text{Ca}^{2+}$   
 B  $^{44}_{22}\text{Ca}^{2+}$   
 C  $^{42}_{22}\text{Ti}$   
 D  $^{44}_{22}\text{Ti}^{2+}$   
 E  $^{44}_{20}\text{Ti}^{2+}$
- 12 In a mixture of  $\text{N}_2$  and  $\text{O}_2$  gases, all the  $\text{N}_2$  molecules and the  $\text{O}_2$  molecules have the same
- A average speed  
 B average kinetic energy  
 C partial pressure  
 D average molecular mass  
 E average momentum
- 13 When ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ , is burned in excess oxygen, carbon dioxide and water are the only products. What is the coefficient of  $\text{O}_2$  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.
- $$\text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g)$$
- 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  $\text{N}_2\text{O}$   
 C  $\text{NO}_2$   
 D  $\text{N}_2\text{O}_4$   
 E  $\text{N}_2\text{O}_5$
- 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  $\text{H}_2\text{S}$     $\text{H}_2\text{Se}$     $\text{H}_2\text{Te}$     $\text{H}_2\text{O}$   
 B  $\text{H}_2\text{O}$     $\text{H}_2\text{S}$     $\text{H}_2\text{Se}$     $\text{H}_2\text{Te}$   
 C  $\text{H}_2\text{Te}$     $\text{H}_2\text{Se}$     $\text{H}_2\text{S}$     $\text{H}_2\text{O}$   
 D  $\text{H}_2\text{O}$     $\text{H}_2\text{Te}$     $\text{H}_2\text{Se}$     $\text{H}_2\text{S}$   
 E  $\text{H}_2\text{S}$     $\text{H}_2\text{O}$     $\text{H}_2\text{Se}$     $\text{H}_2\text{Te}$

- 18 How many unpaired electrons are there in a ground state  $\text{Mn}^{2+}$  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  $P_{\text{atm}} = 750$  mmHg,  $\Delta h_1 = 40$  mm and  $\Delta h_2 = 30$  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 ( $\text{H}_2\text{CO}$ ) molecule? Choose the closest value.
- A  $45^\circ$   
 B  $90^\circ$   
 C  $109^\circ$   
 D  $120^\circ$   
 E  $180^\circ$

- 21 Which of the following diatomic molecules has the strongest bond?
- A  $\text{N}_2$   
 B  $\text{O}_2$   
 C  $\text{F}_2$   
 D  $\text{Cl}_2$   
 E  $\text{Br}_2$

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

- A  $\underline{\text{N}}\text{H}_3$   
 B  $\underline{\text{N}}\text{H}_4^+$   
 C  $\underline{\text{S}}\text{F}_4$   
 D  $\underline{\text{S}}\text{O}_3^{2-}$   
 E  $\underline{\text{S}}\text{O}_3$

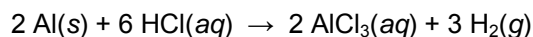
- 23 What is the formula of iron(II) sulfate?

- A  $\text{Fe}_2\text{S}$   
 B  $\text{FeS}_2$   
 C  $\text{FeSO}_4$   
 D  $\text{FeSO}_3$   
 E  $\text{Fe}_2(\text{SO}_4)_3$

- 24 The pH of lemon juice is about 2.3. What is  $[\text{H}^+]$  in lemon juice?

- A  $0.36 \text{ mol L}^{-1}$   
 B  $0.83 \text{ mol L}^{-1}$   
 C  $0.10 \text{ mol L}^{-1}$   
 D  $5.0 \times 10^{-3} \text{ mol L}^{-1}$   
 E  $0.071 \text{ mol L}^{-1}$

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



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<sup>3</sup>  
 B 5.6 × 10<sup>3</sup> L  
 C 11 L  
 D 0.25 L  
 E 0.22 m<sup>3</sup>
- 27** What is the ground state electron configuration of an isolated sulfur (S) atom?
- A 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>2</sup> 3s<sup>2</sup> 3p<sup>2</sup> 4s<sup>2</sup> 3d<sup>2</sup> 4p<sup>2</sup>  
 B 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>1</sup> 3p<sup>3</sup> 3d<sup>5</sup>  
 C 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>4</sup>  
 D 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3p<sup>6</sup>  
 E 1s<sup>2</sup> 2s<sup>2</sup> 2p<sup>6</sup> 3s<sup>2</sup> 3d<sup>6</sup>
- 28** What volume of 0.123 mol/L aqueous H<sub>2</sub>SO<sub>4</sub> is needed to neutralize 40.0 mL of 0.175 mol/L aqueous NaOH? A balanced chemical equation for the reaction is given below.
- $$\text{H}_2\text{SO}_4(\text{aq}) + 2 \text{NaOH}(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + 2 \text{H}_2\text{O}(\text{l})$$
- 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)<sub>2</sub>(aq)?
- A hydrogen, H<sub>2</sub>  
 B oxygen, O<sub>2</sub>  
 C carbon monoxide, CO  
 D nitrogen, N<sub>2</sub>  
 E carbon dioxide, CO<sub>2</sub>
- 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<sup>3</sup> m<sup>3</sup> 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<sup>3</sup> m<sup>3</sup>. 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<sub>2</sub>O  
 B O<sub>2</sub>  
 C O<sub>3</sub>  
 D H<sub>2</sub>O<sub>2</sub>  
 E H<sub>2</sub>SO<sub>4</sub>

- 34** The molar volumes of  $\text{C}_2\text{H}_6(g)$  and  $\text{H}_2(g)$ , 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  $\text{C}_2\text{H}_6(g)$  is smaller than that of  $\text{H}_2(g)$ ?
- A  $\text{C}_2\text{H}_6$  molecules are larger than  $\text{H}_2$  molecules.  
 B The intermolecular attractions in  $\text{C}_2\text{H}_6(g)$  are weaker than they are in  $\text{H}_2(g)$ .  
 C The intermolecular attractions in  $\text{C}_2\text{H}_6(g)$  are stronger than they are in  $\text{H}_2(g)$ .  
 D The average kinetic energy of  $\text{H}_2$  molecules is greater than that of  $\text{C}_2\text{H}_6$  molecules.  
 E The average kinetic energy of  $\text{H}_2$  molecules is less than that of  $\text{C}_2\text{H}_6$  molecules.
- 35** When aqueous sodium carbonate,  $\text{Na}_2\text{CO}_3$ , is treated with dilute hydrochloric acid,  $\text{HCl}$ , the products are sodium chloride, water and carbon dioxide gas. What is the **net ionic equation** for this reaction?
- A  $\text{Na}_2\text{CO}_3(aq) + 2 \text{HCl}(aq) \rightarrow 2 \text{NaCl}(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$   
 B  $\text{CO}_3^{2-}(aq) + 2 \text{HCl}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{CO}_2(g) + 2 \text{Cl}^-(aq)$   
 C  $\text{CO}_3^{2-}(aq) + 2 \text{H}^+(aq) \rightarrow \text{H}_2\text{O}(l) + \text{CO}_2(g)$   
 D  $\text{Na}_2\text{CO}_3(s) + 2 \text{H}^+(aq) \rightarrow 2 \text{Na}^+(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$   
 E  $\text{H}^+(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}(l)$
- 36** Which of the following is the best Lewis structure (i.e., the best electron dot structure) for the  $\text{N}_2\text{O}$  molecule?
- A  $\text{N} \equiv \text{N} - \text{O}$   
 B  $\text{N} \equiv \text{N} = \text{O}$   
 C  $\text{N} = \text{N} - \text{O}$   
 D  $\text{N} = \text{N} = \text{O}$   
 E  $\text{O} = \text{N} - \text{N}$
- 37** A 2.4917-g sample of a hydrate of cobalt (II) fluoride,  $\text{CoF}_2 \cdot x\text{H}_2\text{O}$ , 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  $\text{CoF}_2 \cdot \text{H}_2\text{O}$   
 B  $\text{CoF}_2 \cdot 2\text{H}_2\text{O}$   
 C  $\text{CoF}_2 \cdot 3\text{H}_2\text{O}$   
 D  $\text{CoF}_2 \cdot 4\text{H}_2\text{O}$   
 E  $\text{CoF}_2 \cdot 5\text{H}_2\text{O}$
- 38** How many isomers are there for  $\text{C}_4\text{H}_8$ ? 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  $\text{HNO}_3(aq)$  and  $\text{Ca}(\text{OH})_2(aq)$   
 B  $\text{Zn}(s)$  and  $\text{HCl}(aq)$   
 C  $\text{Zn}(s)$  and  $\text{Cu}(\text{NO}_3)_2(aq)$   
 D  $\text{NaHCO}_3(aq)$  and  $\text{NaOH}(aq)$   
 E  $\text{Na}_2\text{CO}_3(aq)$  and  $\text{CaCl}_2(aq)$
- 40** Which of the following will occur if a  $0.10 \text{ mol L}^{-1}$  solution of acetic acid ( $\text{CH}_3\text{COOH}$ ) is diluted to  $0.010 \text{ mol L}^{-1}$  at constant temperature?
- A the pH will decrease  
 B the dissociation constant of  $\text{CH}_3\text{COOH}$  will increase  
 C the dissociation constant of  $\text{CH}_3\text{COOH}$  will decrease  
 D the hydrogen ion concentration will decrease to  $0.010 \text{ mol L}^{-1}$   
 E the percentage ionization of  $\text{CH}_3\text{COOH}$  will increase

# DATA SHEET AVOGADRO EXAM 2009

**DETACH CAREFULLY**

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

58 <b>Ce</b> 140.1	59 <b>Pr</b> 140.9	60 <b>Nd</b> 144.2	61 <b>Pm</b> (145)	62 <b>Sm</b> 150.4	63 <b>Eu</b> 152.00	64 <b>Gd</b> 157.3	65 <b>Tb</b> 158.9	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.9	68 <b>Er</b> 167.3	69 <b>Tm</b> 168.9	70 <b>Yb</b> 173.0	71 <b>Lu</b> 175.0
90 <b>Th</b> 232.0	91 <b>Pa</b> 231.0	92 <b>U</b> 238.0	93 <b>Np</b> 237.0	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)	103 <b>Lr</b> (260)

**Constants:**

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

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

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

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

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

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

**Conversion factors:**

$$1 \text{ atm} = 101.325 \text{ kPa} = 760 \text{ torr} = 760 \text{ mm Hg}$$

$$0^\circ\text{C} = 273.15 \text{ K}$$

**Equations:**

$$PV = nRT$$

$$k_{t_{1/2}} = 0.693$$

$$\text{pH} = \text{p}K_a + \log \left( \frac{[\text{base}]}{[\text{acid}]} \right)$$

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