

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.

AVOGADRO EXAM 2009 - Answers

- 1 The "lead" of a pencil is mostly
- A lead, Pb
 - *B carbon, C
 - C silicon dioxide, SiO₂
 - D silicon, Si
 - E calcium carbonate, CaCO₃
- 2 How many protons, neutrons and electrons are there in a single atom of $^{209}_{84}\text{Po}$?
- 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 BH₃
 - C CO
 - D H₂S
 - E F₂
- 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 Mg₂P
 - C MgP₂
 - D Mg₂P₃
 - *E Mg₃P₂
- 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

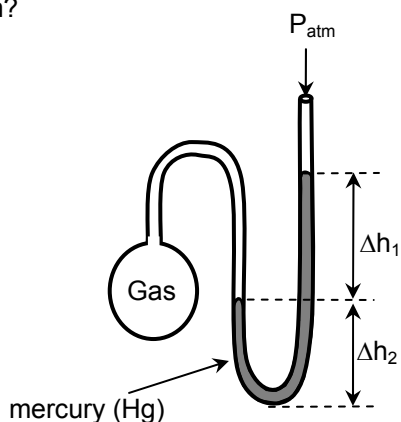
- 10 Which of the following has the highest concentration at equilibrium when one mole of HCl is dissolved in 1.0 L of water at 25 °C?
- *A Cl^-
 B Cl^+
 C Cl_2
 D H_2
 E HCl
- 11 What is the symbol for the atom or ion that results from the addition of two protons to a single atom of $^{42}_{20}\text{Ca}$?
- 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 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, $\text{CH}_3\text{CH}_2\text{OH}$, is burned in excess oxygen, carbon dioxide and water are the only products. What is the coefficient of 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 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 $P_{\text{atm}} = 750 \text{ mmHg}$, $\Delta h_1 = 40 \text{ mm}$ and $\Delta h_2 = 30 \text{ mm}$?

- 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°
- B 90°
- C 109°
- *D 120°
- E 180°

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

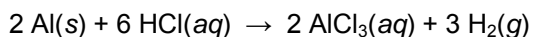
23 What is the formula of iron(II) sulfate?

- A Fe_2S
- B FeS_2
- *C FeSO_4
- D 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 mol L^{-1}
- B 0.83 mol L^{-1}
- C 0.10 mol L^{-1}
- *D $5.0 \times 10^{-3} \text{ mol L}^{-1}$
- E 0.071 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 m³
 *B 5.6 × 10³ L
 C 11 L
 D 0.25 L
 E 0.22 m³
- 27 What is the ground state electron configuration of an isolated sulfur (S) atom?
- A 1s² 2s² 2p² 3s² 3p² 4s² 3d² 4p²
 B 1s² 2s² 2p⁶ 3s¹ 3p³ 3d⁵
 *C 1s² 2s² 2p⁶ 3s² 3p⁴
 D 1s² 2s² 2p⁶ 3s² 3p⁶
 E 1s² 2s² 2p⁶ 3s² 3d⁶
- 28 What volume of 0.123 mol/L aqueous H₂SO₄ 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)₂(aq)?
- A hydrogen, H₂
 B oxygen, O₂
 C carbon monoxide, CO
 *D nitrogen, N₂
 E carbon dioxide, CO₂
- 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 × 10³ m³ 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 × 10³ m³. 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 F₂O
 B O₂
 C O₃
 D H₂O₂
 E H₂SO₄

- 34 The molar volumes of $\text{C}_2\text{H}_6(\text{g})$ and $\text{H}_2(\text{g})$, 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 $\text{C}_2\text{H}_6(\text{g})$ is smaller than that of $\text{H}_2(\text{g})$?
- C_2H_6 molecules are larger than H_2 molecules.
 - The intermolecular attractions in $\text{C}_2\text{H}_6(\text{g})$ are weaker than they are in $\text{H}_2(\text{g})$.
 - *C The intermolecular attractions in $\text{C}_2\text{H}_6(\text{g})$ are stronger than they are in $\text{H}_2(\text{g})$.
 - 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?
- $\text{Na}_2\text{CO}_3(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
 - B $\text{CO}_3^{2-}(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g}) + 2\text{Cl}^-(\text{aq})$
 - *C $\text{CO}_3^{2-}(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$
 - D $\text{Na}_2\text{CO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow 2\text{Na}^+(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
 - E $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$
- 36 Which of the following is the best Lewis structure (i.e., the best electron dot structure) for the N_2O molecule?
- A $\begin{array}{c} \cdot\cdot & \cdot\cdot & \cdot\cdot \\ \vdots & \vdots & \vdots \\ :\text{N} & - & \text{N} & - & \text{O}: \\ \vdots & & \vdots & & \vdots \end{array}$
 - B $\begin{array}{c} \cdot\cdot & & \cdot\cdot \\ \vdots & & \vdots \\ :\text{N} & - & \text{N} & - & \text{O}: \\ \vdots & & \vdots & & \vdots \end{array}$
 - C $\begin{array}{c} \cdot\cdot & & \cdot\cdot \\ \vdots & & \vdots \\ \text{N} & = & \text{N} & - & \text{O}: \\ \vdots & & \vdots & & \vdots \end{array}$
 - *D $\begin{array}{c} \cdot\cdot & & \cdot\cdot \\ \vdots & & \vdots \\ \text{N} & = & \text{N} & = & \text{O}: \\ \vdots & & \vdots & & \vdots \end{array}$
 - E $\begin{array}{c} \cdot\cdot \\ \vdots \\ \text{O} \\ \cdot\cdot \\ / \quad \backslash \\ \text{N} \quad \text{N} \\ \cdot\cdot \quad \cdot\cdot \\ | \quad | \\ \cdot\cdot \quad \cdot\cdot \\ \vdots \quad \vdots \end{array}$
- 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 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 $\text{HNO}_3(\text{aq})$ and $\text{Ca}(\text{OH})_2(\text{aq})$
 - B $\text{Zn}(\text{s})$ and $\text{HCl}(\text{aq})$
 - C $\text{Zn}(\text{s})$ and $\text{Cu}(\text{NO}_3)_2(\text{aq})$
 - D $\text{NaHCO}_3(\text{aq})$ and $\text{NaOH}(\text{aq})$
 - *E $\text{Na}_2\text{CO}_3(\text{aq})$ and $\text{CaCl}_2(\text{aq})$
- 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											18						
1A											8A						
1 H 1.008																	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 B	4 B	5 B	6 B	7 B	8 ←	9 B	10 →	11 B	12 B	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:

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

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

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

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

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

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

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:

$$PV = nRT$$

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

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

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