University of Waterloo

CHEM 13 NEWS EXAM 2009

UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

14 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 12 Chemistry in a nonsemestered school

Code 2 **Ontario**, now studying Grade 12 Chemistry in a semestered school

Code 3 **Ontario**, Grade 12 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 **Québec** CEGEP student

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 In the third period of the elements, how do the atomic radii of the elements vary?

A The radii increase steadily from Na to Ar.

B The radii increase from Na to Al and decrease from Al to Ar.

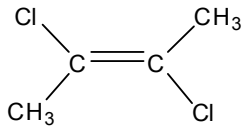
C There is no regular pattern.

D The radii decrease from Na to S and increase from S to Ar.

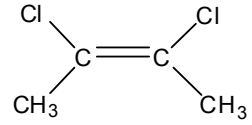
E The radii decrease steadily from Na to Ar.

2 Which of the following compounds has the highest boiling point?

A



B



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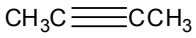

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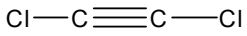
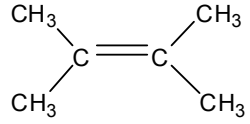


E



3 Nitrous acid, HNO_2, is a weak acid in water. Which of the following statements concerning NO_2^- is **true**?

$K_a = 7.2\times10^{-4}$ at 298 K for HNO_2.

A NO_2^- is a weak base.

B NO_2^- is a strong base.

C NO_2^- is a weak acid.

D NO_2^- is a strong acid.

E NO_2^- is neither an acid nor a base.

4 How many moles of NaOH should be added to 1.0 L of 0.10 mol L^{-1} HCOOH(*aq*) to obtain a solution having a final pH of 4.0 at 298 K? Assume no change in volume. (Choose the closest value.)

$K_a = 1.8\times10^{-4}$ at 298 K for HCOOH.

A 0.018 mol

B 1.8 mol

C 0.26 mol

D 0.064 mol

E 0.0099 mol

5 Which of the following molecules do **not** form hydrogen bonds amongst themselves?

A CH_3COOH

B H_2O_2

C CH_3OCH_3

D HF

E CH_3CH_3OH

6 The reaction below reaches equilibrium in a closed reaction vessel.

$$4\ HCl(aq) + MnO_2(s) \rightleftharpoons Cl_2(g) + 2\ H_2O(l) + Mn^{2+}(aq) + 2\ Cl^-(aq),\ \Delta H < 0$$

Which of the following actions increases the mass of $Cl_2(g)$ in the equilibrium mixture?

A adding some $MnO_2(s)$

B increasing the temperature

C adding some $MnCl_2(s)$

D decreasing the volume of the reaction vessel

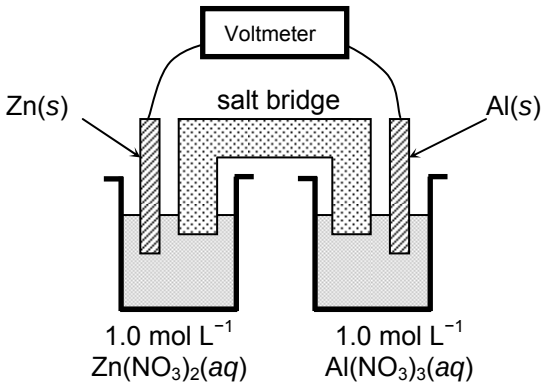
E adding something that precipitates Mn^{2+}

Use the following information and diagram to answer questions 7-10.

A galvanic cell is constructed by placing a strip of zinc into a 1.0 mol L^{-1} solution of zinc nitrate and a strip of aluminum into a 1.0 mol L^{-1} solution of aluminum nitrate. The two metal strips are connected to a voltmeter by wires and a salt bridge connects the solutions. (See the diagram below.) The temperature is 25 °C. The following standard reduction potentials apply:

$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$ $\quad E^o = -1.67$ V

$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$ $\quad E^o = -0.76$ V



7 What is E^o for the cell described above?

A 0.15 V

B 0.91 V

C 2.43 V

D 3.49 V

E 6.53 V

8 In the cell described above, where does reduction occur?

A at the aluminum electrode

B at the zinc electrode

C at the voltmeter

D in the salt bridge

E in the aluminum nitrate solution

9 Considering the standard reduction potentials given in the box on the right, which of the following is the strongest reducing agent under standard conditions?

A Al(*s*)

B $Al^{3+}(aq)$

C Zn(*s*)

D $Zn^{2+}(aq)$

E impossible to determine

10 What is E_{cell} equal to when the cell described in the box reaches equilibrium at 25 °C?

A −2.43 V

B +5.62 V

C 0 V

D 1.06 V

E none of the above

11 A compound is 54.6% C, 36.2% O and 9.2% H by mass. What is the empirical formula of the compound?

A CH_2O

B C_2H_4O

C $C_3H_6O_2$

D C_4H_4O

E C_6H_6O

12 What is the pH of a 1.25×10^{-7} mol L^{-1} HCl(*aq*)?

A 6.90

B 6.74

C 7.00

D 6.67

E less than 6.67

13 Which of the following statements is **true**?

A A single covalent bond consists of a single delocalized electron.

B For a bond formed between a given pair of atoms, the bond dissociation energy increases as the bond order decreases.

C The bond dissociation energy for a C=C bond is twice that of a C−C bond.

D A polar covalent bond results from the transfer of one or more electrons from one atom to another.

E none of the above

14 How many isomers are there for C_5H_{12}?

A one

B two

C three

D four

E more than four

15 The enthalpy change for the reaction below is ΔH = −58 kJ (per mole of N_2O_4 formed).

$$2\ NO_2(g)\ +\ 2\ I^-(aq)\ \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}}\ 2\ SO_4^{2-}(aq)\ +\ I_2(s)$$

If k_1 and k_{-1} are the rate constants for the forward and reverse reactions, respectively, and K_c is the equilibrium constant for the reaction as written, then what effect does increasing the temperature have on the values of k_1, k_{-1} and K_c?

A k_1 increases, k_{-1} decreases, K_c increases

B k_1 increases, k_{-1} increases, K_c increases

C k_1 increases, k_{-1} increases, K_c decreases

D k_1 increases, k_{-1} decreases, K_c decreases

E k_1 decreases, k_{-1} decreases, K_c decreases

16 Consider the thermochemical equations below.

$$C_2H_4(g)\ +\ 3\ O_2(g)\ \rightarrow\ 2\ CO_2(g) + 2\ H_2O(l)$$
$$\Delta H° = -1411\ \text{kJ (per mol } C_2H_4)$$
$$2\ C(s)\ +\ 3\ H_2\ (g)\ +\ ½\ O_2(g)\ \rightarrow\ C_2H_5OH(l)$$
$$\Delta H° = -278\ \text{kJ (per mol } C_2H_5OH)$$
$$C_2H_4(g)\ +\ H_2O(l)\ \rightarrow\ C_2H_5OH(l)$$
$$\Delta H° = -44\ \text{kJ (per mol } C_2H_4)$$

What is $\Delta H°$ for the following reaction? All the answers below are for the combustion of one mole of C_2H_5OH.

$$C_2H_5OH(l)\ +\ 3\ O_2(g)\ \rightarrow\ 2\ CO_2(g)\ +\ 3\ H_2O(l)$$

A −1089 kJ

B 632 kJ

C −1455 kJ

D −1733 kJ

E −1367 kJ

17 A 10.0-L gas cylinder contains neon gas with a measured pressure of 5.50 atm at 298 K. The 10.0-L cylinder is then connected to an empty gas cylinder of unknown volume, and the neon gas expands to fill both cylinders. If the final pressure is found to be 3.76 atm at 298 K, then what is the volume of the second cylinder?

A 14.6 L

B 6.52 L

C 10.0 L

D 4.63 L

E 9.26 L

18 Which of the following correctly describes what happens when aqueous solutions of ammonium carbonate, $(NH_4)_2CO_3$, and potassium bromide, KBr, are mixed?

A Br^- neutralizes NH_4^+.

B $K_2CO_3(s)$ precipitates.

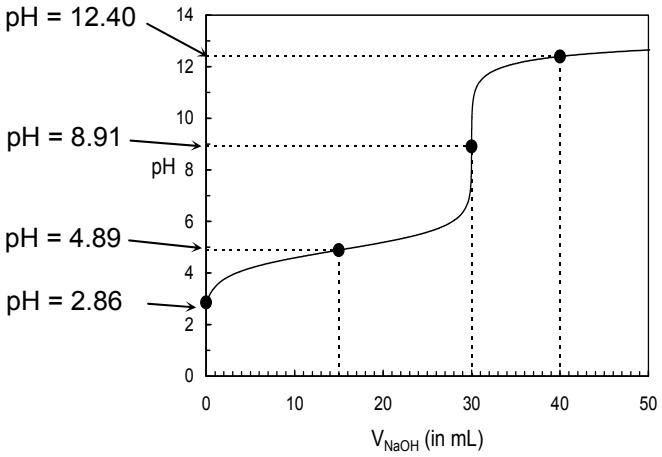
C HBr is formed.

D $NH_4Br(s)$ precipitates.

E none of the above

Use the information and diagram below to answer questions 19-21.

A 40.0-mL sample of a weak monoprotic acid, HA, is titrated with 0.20 mol L^{-1} NaOH(*aq*). The titration curve is shown below.



19 For the titration described above, which of the following is true at the equivalence point?

A $[HA] = [Na^+]$

B $[A^-] = [HA]$

C $[Na^+] = [A^-]$

D $[H^+] = [OH^-]$

E $[A^-] = [H^+]$

20 Based on the titration curve above, what was the concentration of the original sample solution (i.e. before the titration started)?

A 0.63 mol L^{-1}

B 0.15 mol L^{-1}

C 0.24 mol L^{-1}

D 0.067 mol L^{-1}

E 0.20 mol L^{-1}

21 Based on the titration curve above, what is the ionization constant (K_a) for the acid, HA?

A $10^{-12.40}$

B $10^{-8.91}$

C $10^{-4.89}$

D $10^{-2.86}$

E $10^{+2.86}$

22 How many unpaired electrons are there in the nickel (Ni) atom in its ground state electron state?

A 5

B 4

C 6

D 2

E 0

23 Equal volumes of 0.1 mol L^{-1} HCl(*aq*) and 0.1 mol L^{-1} HF(*aq*) are titrated in separate experiments with 0.1 mol L^{-1} NaOH(*aq*). Which of the following would be equal for both titrations?

A the initial pH (i.e. the pH before any NaOH is added)

B the pH when half the acid has been neutralized (i.e. the pH at the half-neutralization point)

C the pH at the equivalence point

D the volume of NaOH required to reach the equivalence point

E none of the above

24 For the reaction below, $K_c = 7.8\times10^8$. What is the equilibrium concentration of NH_3 when 1.00 mol each of $Zn(NO_3)_2$ and NH_3 are dissolved in water to make 1.0 L of solution?

$$Zn^{2+}(aq) + 4\ NH_3(aq) \rightleftharpoons Zn(NH_3)_4^{2+}(aq)$$

A 0 mol L^{-1}

B 1.3×10^{-9} mol L^{-1}

C 0.75 mol L^{-1}

D 0.25 mol L^{-1}

E 4.5×10^{-3} mol L^{-1}

25 Which of the following molecules is polar?

A CS_2

B N_2O

C CCl_4

D PF_5

E SO_3

26 Consider the compounds NaCl, AgCl and CO_2 in terms of their solubilities in water. Which of these compounds exhibits an increase in solubility if the temperature is lowered and the pressure is increased?

A NaCl only

B AgCl only

C CO_2 only

D NaCl and AgCl

E NaCl, AgCl and CO_2

27 When a 1.00 mol L^{-1} solution of $M^{2+}(aq)$ is electrolyzed with a current of 2.5 amperes for 0.2 hours, 0.485 g of M(*s*) are deposited. What is the identity of M? (Note: 1 ampere = 1 C s^{-1})?

A Cr

B Rh

C Na

D Mg

E Ag

28 Iron (III) oxide, Fe_2O_3, reacts with hydrochloric acid to produce only water and a salt. What is the formula of the salt?

A $FeCl_3$

B $FeCl_2$

C FeCl

D Fe_2Cl_3

E $FeCl_6$

29 The unbalanced chemical equation for the oxidation of Zn by NO_3^- is given below. The reaction occurs in aqueous basic solution.

$$Zn + NO_3^- \rightarrow Zn(OH)_4^{2-} + NH_3$$

How many moles of NO_3^- are required to oxidize exactly one mole of Zn?

A 1 mol

B ¼ mol

C 4 mol

D 8 mol

E ⅛ mol

30 Two students each made four measurements of the mass of an object. Their results are shown in the table below.

	Student A	Student B
Measurements:	51.6 g	50.1 g
	50.8 g	49.6 g
	52.2 g	51.0 g
	50.2 g	49.4 g
Average:	51.3 g	50.0 g

If the exact mass of the object is 51.0 g, then which of the following statements is true?

A Student A's results are more accurate and more precise.

B Student B's results are more accurate and more precise.

C Student A's results are more accurate but less precise.

D Student B's results are more accurate but less precise.

E The two sets of results are equally precise.

31 Which of the following compounds displays the greatest ionic character in its bonds?

A NO_2

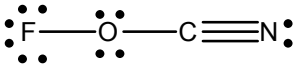
B CO_2

C H_2O

D NH_3

E F_2O

32 What is the oxidation state of oxygen in FOCN? The molecular structure of FOCN is shown below.



A zero

B +2

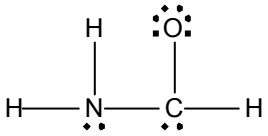
C −2

D +1

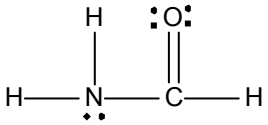
E −1

33 Experiment shows that in the formamide molecule, H_2NCHO, the H-N-H angle is 119° and the N-C-O angle is 124°. Which of the following structures is an acceptable structure for H_2NCHO and is consistent with the experimentally-determined bond angles?

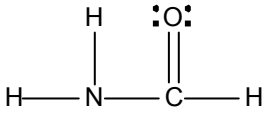
A



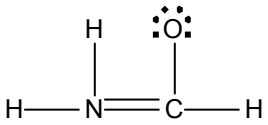
B



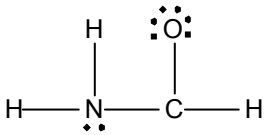
C



D



E



34 Which of the following best describes the bonding in the N_2 molecule?

A one σ bond and one π bond

B two σ bonds and one π bond

C two π bonds

D three π bonds

E one σ bond and two π bonds

35 When building up the electron configuration of a neutral atom, which orbital fills immediately after the 5s orbital?

A 4d

B 4f

C 5p

D 6s

E 5d

36 Perovskite is a mineral containing Ca, O and Ti. The smallest repeating unit in the structure of perovskite is shown below. (There is a single titanium atom at the centre of the cube.) By considering the total number of atoms of each type that lie **inside** the cube below, determine the formula of perovskite. What is the formula of perovskite?

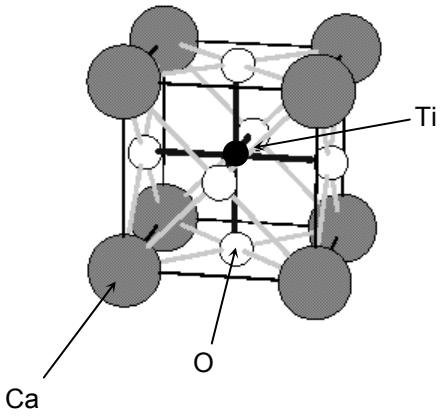
A CaOTi

B CaO_6Ti

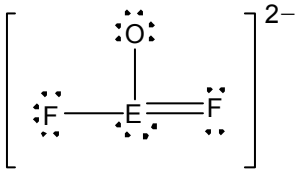
C Ca_8O_6Ti

D Ca_2O_3Ti

E CaO_3Ti



37 Consider the Lewis structure shown below for the polyatomic ion, EOF_2^{2-}. The central atom, E, is an unidentified element. Which of the following atoms could E represent?



A oxygen (O)

B sulfur (S)

C bromine (Br)

D nitrogen (N)

E xenon (Xe)

38 Consider the following reaction mechanism.

$(CH_3)_3CBr \rightleftarrows (CH_3)_3C^+ + Br^-$

$(CH_3)_3C^+ + N_3^- \rightarrow (CH_3)_3CN_3$

According to this mechanism, $(CH_3)_3C^+$ is

A a reaction product

B a reaction intermediate

C an activated complex

D a catalyst

E a Lewis base

39 What is the final temperature when 100.0 mL of water at 90.0 °C and 200.0 mL of water at 10.0 °C are mixed? Assume no heat is lost to the surroundings. Choose the closest value.

A 40 °C

B 50 °C

C 70 °C

D 80 °C

E 100 °C

Properties of water

density = 1.0 g mL^{-1}

specific heat = 4.18 J g^{-1} $°C^{-1}$

heat of vaporization = 2260 J g^{-1}

40 Which of the following is present in the greatest number in a dilute sulfuric acid (H_2SO_4) solution?

A H_2SO_4 molecules

B HSO_4^- ions

C SO_4^{2-} ions

D H^+ ions

E OH^- ions

DATA SHEET
CHEM 13 NEWS 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

$0^oC = 273.15$ K

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