UNIVERSITY OF WATERLOO

CHEM 13 NEWS EXAM 2011

UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

12 MAY 2011 **TIME: 75 MINUTES**

This exam is being written by several thousand students. Please be sure that you follow the instructions below.
We'll send your teacher 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 At 25 ^{o}C and 100 kPa, most of the known elements are

A monatomic gases

B diatomic gases

C liquids

D metallic solids

E non-metallic or semi-metallic solids

2 Which of the following series lists the compounds in order of increasing boiling point? (from lowest to highest)

A $H_2Te < H_2Se < H_2S < H_2O$

B $H_2S < H_2Se < H_2Te < H_2O$

C $H_2S < H_2O < H_2Se < H_2Te$

D $H_2O < H_2S < H_2Se < H_2Te$

E $H_2O < H_2Te < H_2Se < H_2S$

3 In which of the following compounds does oxygen have the highest oxidation state?

A CsO_2

B H_2O

C O_2

D H_2O_2

E OF_2

4 Which of the following processes is the most endothermic?

A $H_2O(l) \longrightarrow H_2O(g)$

B $F(g) + e^- \longrightarrow F^-(g)$

C $NaCl(s) \xrightarrow{H_2O} NaCl(aq)$

D $Na(g) \longrightarrow Na^+(g) + e^-$

E $K^+(g) + Cl^-(g) \longrightarrow KCl(s)$

5 Which of the following atoms has electrons in its outermost shell arranged in the configuration $4s^2\ 4p^3$? Assume each atom is in its lowest energy state.

A Rb

B Kr

C As

D Cr

E Sb

6 The following reaction reaches equilibrium in a closed reaction vessel at 200 ^{o}C.

$CO(g) + 3\ H_2(g) \rightleftharpoons CH_4(g) + H_2O(g),\ \Delta H^o = -206$ kJ

Which of the following actions causes the reaction to proceed from left to right in order to restore equilibrium?

A increasing the volume of the container, holding temperature constant

B adding some CH_4 gas to the system, with volume and temperature held constant

C adding some H_2 gas to the system, with volume and temperature held constant

D increasing the temperature, holding the pressure constant

E removing some CO gas from the system, with volume and temperature held constant

7 At a certain temperature, the following equilibrium constants have been measured.

$A_2(s) + 2\ B(g) \rightleftharpoons 2\ C(g) \qquad K_1 = 36$

$D(s) + 2\ E(g) \rightleftharpoons C(g) \qquad K_2 = 20$

What is the equilibrium constant at the same temperature for the reaction below?

$\frac{1}{2}\ A_2(s) + B(g) \rightleftharpoons D(s) + 2\ E(g)$

A 720

B 1.8

C 0.56

D 0.30

E 0.090

8 In a particular solution, $[Br^-] = 0.020$ mol L^{-1} and $[CrO_4^{2-}] = 0.0030$ mol L^{-1}. Finely-divided solid silver nitrate, $AgNO_3$, is slowly added to the solution. What is $[Br^-]$ when $Ag_2CrO_4(s)$ just begins to precipitate?

	K_{sp}
Ag_2CrO_4	1.9×10^{-12}
AgBr	5.2×10^{-13}

A 2.1×10^{-8} mol L^{-1}

B 6.0×10^{-8} mol L^{-1}

C 2.7×10^{-7} mol L^{-1}

D 5.2×10^{-13} mol L^{-1}

E 6.4×10^{-4} mol L^{-1}

9 What is the formula of the stable compound formed by magnesium and nitrogen?

A MgN

B Mg_2N

C Mg_3N_2

D Mg_2N_3

E MgN_2

10 Which of the following ions has the smallest tendency to be protonated when dissolved in liquid acetic acid, $CH_3COOH(l)$?

A hydroxide,OH^-

B fluoride, F^-

C chloride, Cl^-

D bromide, Br^-

E iodide, I^-

11 X-ray radiation is more energetic than microwave radiation because

A photons of X-ray radiation travel faster than those of microwave radiation

B photons of X-ray radiation are heavier than those of microwave radiation

C X-ray radiation has a higher frequency than does microwave radiation

D X-ray radiation has a longer wavelength than does microwave radiation

E photons of X-ray radiation travel slower than those of microwave radiation

12 Which of the following contains only single bonds?

A NO^+

B CO

C CN^-

D N_2^{2-}

E O_2^{2-}

13 What is the empirical formula of a compound that is 66.64% carbon, 7.45% hydrogen and 25.91% nitrogen by mass?

A C_3H_4N

B $C_3H_4N_2$

C C_3H_3N

D C_4H_4N

E $C_4H_3N_2$

14 Let $D_{C=C}$ represent the C=C bond dissociation energy in ethene, $H_2C=CH_2$, and D_{C-C} the C-C bond dissociation energy in ethane, H_3C-CH_3. How do these bond dissociation energies compare?

A $D_{C=C}$ equals D_{C-C}

B $D_{C=C}$ is exactly equal to $2 \times D_{C-C}$

C $D_{C=C}$ is exactly equal to $\frac{1}{2} \times D_{C-C}$

D $D_{C=C}$ is greater than D_{C-C} but less than $2 \times D_{C-C}$

E $D_{C=C}$ is greater than $2 \times D_{C-C}$

15 Which of the following bonds is most polar?

A B−O

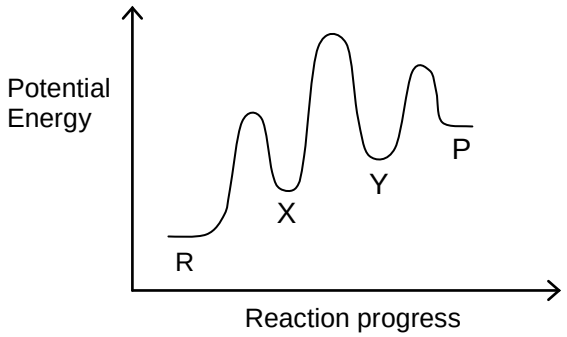
B B-F

C C-O

D C=O

E C−F

16 Consider the following energy level diagram for the reaction R → P.



Which of the following statements is **false**?

A The conversion of R to P occurs via a two-step process.

B X and Y represent reaction intermediates.

C The conversion of R to P is endothermic.

D At equilibrium, the rate of conversion of R to P is equal to the rate of conversion of P to R.

E The rate-limiting step is the conversion of X to Y.

17 A solution in which the bromide concentration is 2.0×10^{-5} mol L^{-1} is in equilibrium with solid AgBr and solid AgI. What is the concentration of iodide ion?

	K_{sp}
AgBr	5.2×10^{-13}
AgI	1.5×10^{-16}

A 2.6×10^{-8} mol L^{-1}

B 5.8×10^{-9} mol L^{-1}

C 1.5×10^{-16} mol L^{-1}

D 7.5×10^{-12} mol L^{-1}

E 2.9×10^{-4} mol L^{-1}

18 Consider the hydrogen halides HF, HCl, HBr and HI. Which of the statements about them is **true**?

A They are all strong acids.

B They are all weak acids.

C The boiling point increases with molar mass.

D The bond dissociation energy increases with molar mass.

E none of above

19 For the reaction below, $K_c = 1.0\times10^{-20}$.

$$2\ A(g) + B(g) \rightleftharpoons C(g)$$

In an experiment, 1.0 mol each of A, B and C are placed in an empty 1.0 L container and then the container is quickly sealed. When equilibrium is established, which of the following will be **true**?

A [A] < [B] < [C]

B [A] > [B] > [C]

C [A] = [B] = [C]

D [A] = [B] < [C]

E [A] > [B] = [C]

20 What percentage of CH_3COOH molecules are ionized in 1.8×10^{-5} mol L^{-1} $CH_3COOH(aq)$?

$K_a(CH_3COOH) = 1.8\times10^{-5}$

A 1.8%

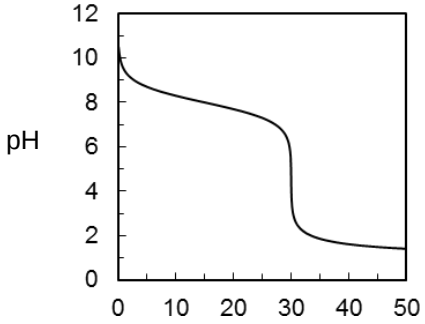
B 4.2%

C 42%

D 62%

E almost 100%

21 A technician recorded the following curve during a titration.



The curve represents the titration of a

A weak acid by adding strong base

B strong acid by adding weak base

C strong base by adding weak acid

D strong base by adding strong acid

E a weak base by adding strong acid

Use the table of standard reduction potentials given below to answer questions 22 through 25.

Half–Reaction	E°
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80 V
$O_2(g) + 2\,H_2O(l) + 4e^- \rightleftharpoons 4\,OH^-(aq)$	+0.40 V
$2\,H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.0 V
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14 V
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.25 V
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.41 V
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76 V
$2\,H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2\,OH^-(aq)$	–0.83 V
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.66 V

22 Which of the following is the strongest oxidizing agent under standard conditions?

A $Ag^+(aq)$

B Ag(s)

C $H^+(aq)$

D Al(s)

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

23 When $Ag^+(aq)$ reacts completely with exactly one mole of $H_2(g)$ under standard conditions, how many moles of solid Ag are produced?

A 1 mol

B 2 mol

C 0.5 mol

D 4 mol

E 0.25 mol

24 What is E° for the reaction $2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l)$?

A 1.23 V

B 0.43 V

C 4.06 V

D 0.43 V

E 2.06 V

25 Which of the following reagents would spontaneously reduce $Ni^{2+}(aq)$ to Ni(s) under standard conditions?

A $Ag^+(aq)$

B Ag(s)

C Zn(s)

D Sn(s)

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

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26 Consider the ions K^+, Ca^{2+}, Cl^- and S^{2-}. In which series are the species listed in order of decreasing radius? (from largest to smallest)

A $S^{2-} > Cl^- > K^+ > Ca^{2+}$

B $K^+ > Ca^{2+} > S^{2-} > Cl^-$

C $S^{2-} > Ca^{2+} > Cl^- > K^+$

D $Ca^{2+} > K^+ > Cl^- > S^{2-}$

E $Ca^{2+} > K^+ > S^{2-} > Cl^-$

27 A solution is prepared by completely dissolving a solid mixture of NaOH and $Mg(OH)_2$ in water. For the resulting solution, which of the following conditions must be satisfied?

A $[Na^+] = [Mg^{2+}] = [OH^-]$

B $[Na^+] = [Mg^{2+}] = 3\,[OH^-]$

C $[Na^+] + [Mg^{2+}] = 3\,[OH^-]$

D $[Na^+] + 2\,[Mg^{2+}] = [OH^-]$

E $[Na^+] + [Mg^{2+}] = [OH^-]$

28 What is the minimum volume of water needed to dissolve completely 1.0 g SrF_2?

$K_{sp}(SrF_2) = 2.8\times10^{-9}$
Sr, 87.62 g mol^{-1}
F, 19.00 g mol^{-1}

A 9.0 L

B 150 L

C 10.5 L

D 5.6 L

E 2.8 L

29 What is the molecular geometry of SF_4?

A T-shaped

B tetrahedral

C see-saw

D square planar

E square pyramidal

30 In the incomplete equation below, NH_3 acts as a Bronsted-Lowry acid and "X" represents a Bronsted-Lowry base. What is the conjugate base of NH_3?

$$NH_3 + X \rightarrow ?$$

A X

B XH^+

C NH_4^+

D NH_2^-

E OH^-

31 What is the general trend observed for the first ionization energies of the elements in groups 13 through 17?

A Ionization energies tend to increase from left to right in a period, and are approximately constant in a group.

B Ionization energies tend to increase from left to right in a period, and decrease from top to bottom in a group.

C Ionization energies tend to decrease from left to right in a period, and increase from top to bottom in a group.

D Ionization energies tend to decrease from left to right in a period, and decrease from top to bottom in a group.

E Ionization energies are approximately constant in a period, and decrease from top to bottom in a group.

32 What is the hybridization of the sulfur atom in the SO_3^{2-} ion?

A sp

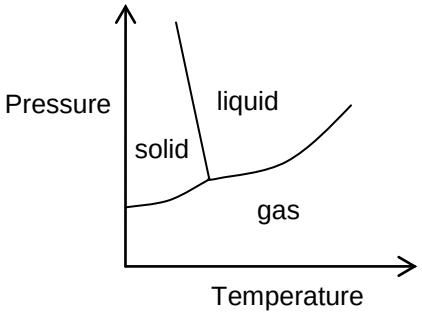
B sp^2

C sp^3

D sp^3d

E sp^3d^2

33 The phase diagram for an unidentified substance is shown below.



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

A Liquid can be converted to solid by increasing the pressure at constant temperature.

B The melting temperature of the solid increases as pressure increases.

C Solid cannot be converted into gas without first being converted to liquid.

D There is only one combination of temperature and pressure for which solid, liquid and gas can coexist.

E More than one of the statements above are true.

34 When the following equation is balanced using the smallest whole number coefficients, what is the coefficient of O_2?

$$NH_3 + O_2 \rightarrow NO + H_2O$$

A 2

B 3

C 4

D 5

E 6

35 What is [CH_3COOH] at equilibrium if 0.10 moles of CH_3COOH and 0.15 moles of NaOH are dissolved in enough water to make 1.0 L of solution at 25 ^oC? For CH_3COOH, $K_a = 1.8\times10^{-5}$ at 25 ^oC.

A 0 mol L^{-1}

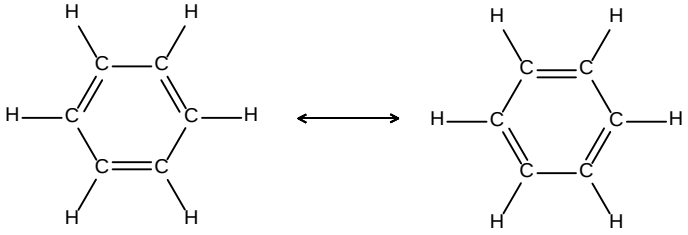
B 1.8×10^{-5} mol L^{-1}

C 5.6×10^{-10} mol L^{-1}

D 1.1×10^{-9} mol L^{-1}

E 1.3×10^{-3} mol L^{-1}

36 The following diagram is sometimes used to illustrate the structure of benzene, C_6H_6.



Which of the statements concerning the structure of benzene is **false**?

A The double bonds oscillate rapidly back and forth between adjacent pairs of carbon atoms.

B The H-C-C angles are 120^o.

C The carbon atoms form a flat hexagonal ring.

D The oxidation state of carbon is −1.

E The carbon-carbon bonds are all the same length.

37 A particular substance, X, decomposes such that its concentration decreases by a factor of two every 35 s. If the initial concentration of X was 1.0 mol L^{-1}, what is [X] after exactly 140 s?

A 0.33 mol L^{-1}

B 0.13 mol L^{-1}

C 0.25 mol L^{-1}

D 0.063 mol L^{-1}

E 0.67 mol L^{-1}

38 The bond dissociation energies for F_2 and Cl_2 are approximately 158 and 242 kJ mol^{-1}, respectively. Given that the enthalpy change for the reaction below is $\Delta H = -54$ kJ mol^{-1}, what is the bond dissociation energy for the F-Cl bond?

$$\tfrac{1}{2}\, F_2(g) + \tfrac{1}{2}\, Cl_2(g) \rightarrow FCl(g)$$

A 200 kJ mol^{-1}

B 254 kJ mol^{-1}

C 146 kJ mol^{-1}

D 454 kJ mol^{-1}

E 346 kJ mol^{-1}

39 Which of the following has the greatest number of unpaired electrons in its ground electronic state?

A Al

B Cl

C Ti^{2+}

D Zn^{2+}

E S^{2-}

40 Let HA represent a weak monoprotic acid with $K_a = 1.0\times10^{-5}$. In an experiment, a 50.0 mL sample of 0.10 mol L^{-1} HA(aq) is titrated with 0.10 mol L^{-1} NaOH(aq). At which point during the titration are the equilibrium concentrations of H^+ and OH^- equal?

A after the addition of exactly 25.0 mL of NaOH(aq)

B after the addition of slightly less than 50.0 mL of NaOH(aq)

C after the addition of exactly 50.0 mL of NaOH(aq)

D after the addition of more than 50.0 mL of NaOH(aq)

E The equilibrium concentrations of H^+ and OH^- are never equal.

DATA SHEET
CHEM 13 NEWS EXAM 2011

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	57-71 **La-Lu**	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	89-103 **Ac-Lr**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Sg**	112 **Cn**						

57 **La** 138.9	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
89 **Ac** 227.	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 ^{o}C = 273.15 K

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