University of Waterloo

CHEM 13 NEWS EXAM 2010

UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

20 MAY 2010 **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 Of the first 18 elements, how many are gases at 25 °C and 100 kPa?

A less than seven

B seven

***C** eight

D nine

E more than nine

2 Which of the following substances has the highest vapour pressure at 25 °C?

A CH_3OH

B $CH_3CH_2CH_2OH$

C LiF

***D** H_2CO

E Li

3 Which of the following compounds has the highest melting point?

A LiF

***B** ZnO

C LiCl

D NaF

E NaCl

Ionic Radii (in pm)			
Li^+,	68	F^-,	136
Zn^{2+},	74	O^{2-},	140
Na^+,	97	Cl^-,	181

4 For a given substance, which of the following phase transitions is the most exothermic?

A solid → liquid

B gas → liquid

C liquid → gas

D solid → gas

***E** gas → solid

5 What is the ground state electron configuration of selenium, Se?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4p^4$

B $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4p^6$

***C** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$

E $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4p^4\ 4d^{10}$

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

$C_6H_{12}O_6(s) \rightleftharpoons 2\ C_2H_5OH(l) + 2\ CO_2(g), \quad \Delta H^o = -72$ kJ

Which of the following actions causes an increase in the value of K_c?

(i) adding some $CO_2(g)$

(ii) transferring the reaction mixture to a vessel of larger volume

(iii) increasing the temperature

A (i) only

B (ii) only

C (iii) only

D (i) and (ii)

***E** none of the above

7 Given that

$2\ Hg^{2+}(aq) + 2\ e^- \rightleftharpoons Hg_2^{2+}(aq) \qquad E^o = 0.920$ V

$Ag^+(aq) + e^- \rightleftharpoons Ag(s) \qquad E^o = 0.799$ V

what is E^o for the reaction below?

$2\ Ag^+(aq) + Hg_2^{2+}(aq) \rightleftharpoons 2\ Ag(s) + 2\ Hg^{2+}(aq)$

A 0.121 V

***B** −0.121 V

C 0.678 V

D −0.678 V

E 0.339 V

8 Given that

$Fe^{2+}(aq) + 2\ e^- \rightleftharpoons Fe(s) \qquad E^o = -0.40$ V

$2\ H^+(aq) + 2\ e^- \rightleftharpoons H_2(g) \qquad E^o = 0.00$ V

$Br_2(l) + 2\ e^- \rightleftharpoons 2\ Br^-(aq) \qquad E^o = +1.09$ V

which of the following is the strongest reducing agent under standard conditions?

A $Fe^{2+}(aq)$

B $H^+(aq)$

C $Br_2(l)$

D $Br^-(aq)$

***E** $H_2(g)$

9 What is the coefficient of O_2 when the following equation is balanced?

$1\ C_{10}H_8(s) + x\ O_2(g) \rightarrow y\ CO_2(g) + z\ H_2O(l)$

A 1

B 6

C 7

***D** 12

E 14

10 Which of the following will react appreciably with water at room temperature and pressure to produce hydrogen?

***A** NaH

B NH_3

C CH_4

D HCl

E H_2S

11 Cesium forms a number of compounds with oxygen. A particular compound is found to be 26.5% oxygen by mass. What is the formula of this compound?

A Cs_2O

B Cs_2O_2

C CsO_2

***D** CsO_3

E CsO_4

Molar masses (in g/mol)
O, 16.00
Cs, 132.9

12 Which of the following is the strongest acid in water?

A HBr

B $HOBrO_2$

C HF

D $HOIO_2$

***E** HI

13 Let the energy of the 2s level in a hydrogen atom be $-E$. What is the energy of the 3s level?

A $-\frac{2}{3}E$

***B** $-\frac{4}{9}E$

C $-\frac{3}{2}E$

D $-\frac{9}{4}E$

E $-3E$

14 Natural oils, such as vegetable oil, are converted into solid, edible fats by a process called

A fusion

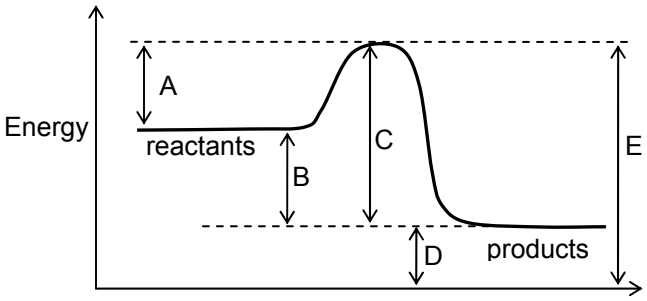
***B** hydrogenation

C crystallization

D flash freezing

E saponification

15 The value for the activation energy of the forward reaction is represented by which letter in the diagram below?



***A** A

B B

C C

D D

E E

16 The heat of combustion of C(s) is −394 kJ/mol and that of CO(g) is −111 kJ/mol. What is the enthalpy change for the reaction below?

$$CO(g) \rightarrow C(s) + \tfrac{1}{2} O_2(g)$$

A 505 kJ

***B** 283 kJ

C 111 kJ

D −283 kJ

E −505 kJ

17 Exactly 850 mL of O_2 gas is collected over water at 30.0 °C using the setup below. Given that the barometric pressure was 98.5 kPa and the vapour pressure of water is 4.24 kPa at 30 °C, what volume would the pure O_2 gas occupy at 98.5 kPa and 30 °C?

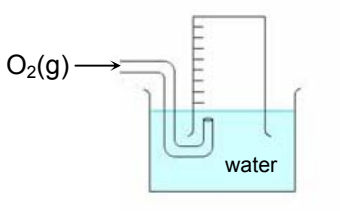
***A** 813 mL

B 818 mL

C 850 mL

D 882 mL

E 888 mL



18 How are the boiling and freezing points of water affected by the addition of a soluble salt?

A The freezing and boiling points are both lowered.

B The freezing and boiling points are both raised.

***C** The freezing is lowered and the boiling point is raised.

D The freezing is raised and the boiling point is lowered.

E The boiling and freezing points are not affected.

19 The reaction below comes to equilibrium in a closed reaction vessel of volume 2.50 L.

$$2\ NO_2(g) \rightleftharpoons 2\ NO(g) + O_2(g)$$

At equilibrium, there are 3.0 mol NO, 4.00 mol O_2 and 22.0 mol NO_2. What is the value of K_c for the reaction above?

***A** 0.0298

B 33.6

C 1.83

D 13.4

E 0.218

20 Which of the following occurs if a 0.10 mol/L solution of a weak acid is diluted to 0.010 mol/L at constant temperature?

A The hydrogen ion concentration decreases to 0.010 mol/L.

B The pH decreases.

C The ionization constant, K_a, decreases.

***D** The percentage ionization increases.

E all of the above

21 What is the equilibrium concentration of Ag^+ in solution when 0.50 L of 0.10 mol/L $AgNO_3(aq)$ and 0.50 L of 0.20 mol/L NaCl(aq) are mixed? Assume the temperature is 25 °C.

For AgCl, $K_{sp} = 1.8\times10^{-10}$ at 25 °C.

A 0 mol/L

***B** 3.6×10^{-9} mol/L

C 9.0×10^{-10} mol/L

D 1.3×10^{-5} mol/L

E 0.05 mol/L

22 In which ionic compound does the cation have the same number of electrons as the anion?

A LiF

B NaCl

C CaO

***D** MgF_2

E KI

23 How many moles of NaOH or HCl should be added to 1.0 L of 0.010 mol L^{-1} formic acid (HCOOH) solution to obtain a solution with pH = 3.50? Assume no change in volume. (Choose the closest value.)

$K_a = 1.8\times10^{-4}$ for HCOOH

***A** 3.6×10^{-3} mol NaOH

B 3.6×10^{-3} mol HCl

C 5.8×10^{-3} mol NaOH

D 5.8×10^{-3} mol HCl

E 3.2×10^{-4} mol HCl

24 For the reaction below, $K_c = 6.3\times10^{4}$ at 25 °C.

$$2\ NO(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g)$$

In an experiment, carried out at 25 °C, 1.0 mol NO and 1.0 mol Cl_2 are added to an evacuated reaction vessel of volume 1.0 L and then the vessel is quickly sealed. What is the equilibrium concentration of NO?

A 0.50 mol/L

***B** 5.6×10^{-3} mol/L

C 2.8×10^{-3} mol/L

D 1.6×10^{-5} mol/L

E 7.9×10^{-6} mol/L

25 What is the molecular geometry of the BrF_3 molecule? The Br atom is the central atom and all the F atoms are bonded directly to Br.

A trigonal planar

B trigonal bipyramidal

***C** T-shaped

D square planar

E trigonal pyramidal

26 When 0.012 moles of a monoprotic acid is dissolved in water to give 1.0 L of solution at 25 °C, the final pH is 1.95. What is K_a for this acid?

A 2.9×10^{-1}

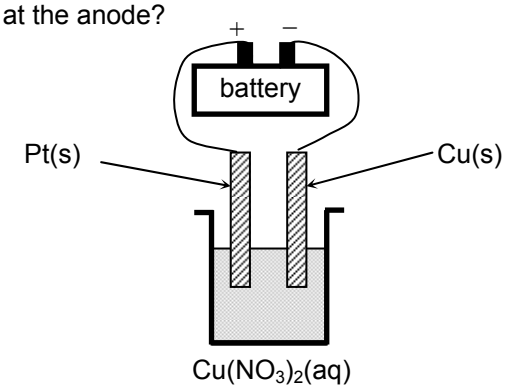
B 1.1×10^{-2}

***C** 1.6×10^{-1}

D 1.3×10^{-4}

E 1.5×10^{-6}

27 A 1.00 mol/L solution of $Cu(NO_3)_2(aq)$ is electrolyzed using the setup illustrated below. What is the reaction occurring at the anode?



A $Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$

B $Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$

C $2\ H_2O(l) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-(aq)$

***D** $2\ H_2O(l) \rightarrow O_2(g) + 4\ H^+(aq) + 4\ e^-$

E $Pt(s) \rightarrow Pt^{4+}(aq) + 4\ e^-$

28 Which of the following forms of radiation has the longest wavelength?

A infrared

B x-ray

***C** microwave

D ultraviolet

E visible

29 In the **unbalanced** chemical equation below, *x*, *y* and *z* are coefficients to be determined.

$$1\ Fe^{2+} + x\ Br_2 \rightarrow y\ Fe^{3+} + z\ Br^-$$

When the equation is properly balanced, what is the value of *z*?

***A** 1

B 2

C ½

D 4

E ¼

30 If the pH of a solution changed from 4.0 to 8.0, what happened to the hydrogen ion concentration?

A It increased by a factor of two.

B It decreased by a factor of two.

C It increased by a factor of 10^4.

***D** It decreased by a factor of 10^4.

E It decreased by a factor of 10^2.

31 Which of the following compounds displays only covalent bonding?

A NH_4OH

B Li_2O

***C** HOCN

D $NaNO_3$

E KH

32 How many sigma (σ) and pi (π) bonds are there in the allene molecule, H_2CCCH_2?

***A** six σ bonds and two π bonds

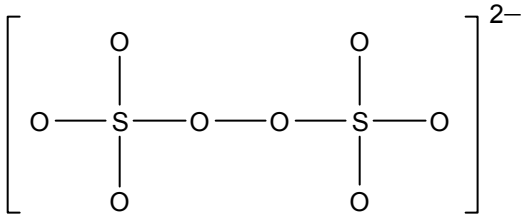
B two σ bonds and six π bonds

C four σ bonds and four π bonds

D eight σ bonds and no π bonds

E two σ bonds and six π bonds

33 What is the oxidation state of each sulfur atom in the peroxydisulfate ion, $S_2O_8^{2-}$? In the structure below, lone pairs are <u>not</u> shown.



A −2

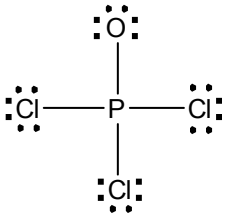
B 0

C +4

***D** +6

E +7

34 A Lewis structure for $POCl_3$ is shown below.



Which of the following statements is correct?

A This is most important Lewis structure for the $POCl_3$ molecule.

B The phosphorus atom is sp^2-hybridized.

C The Cl-P-Cl angles are 90^o.

D The oxidation state of phosphorus is +4.

***E** None of the statements above are true.

35 What is the maximum number of electrons that can have a principal quantum number of 4 within one atom?

A two

B four

C eight

D sixteen

***E** thirty-two

36 How many unpaired electrons are there in a Mn^{2+} ion in its ground electronic state? The atomic number of manganese is $Z = 25$.

A 0

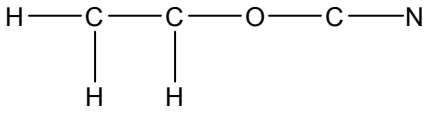
B 2

C 3

***D** 5

E 6

37 The skeletal structure below for the CH_2CHOCN molecule is incomplete; additional bonding pairs or lone pairs must be added. When the structure is properly completed, how many lone pairs are there in this molecule?



A none

B one

C two

***D** three

E four

38 When temperature is increased, the rate of a reaction also increases. This observation is best explained by

A an increase in the frequency of molecular collisions

B a decrease in the activation energy, E_a, for the reaction

C an increase in the activation energy, E_a, for the reaction

D a decrease in the enthalpy change, ΔH, for the reaction

***E** an increase in the fraction of molecules that have enough energy to react

39 Which of the following would need the smallest quantity of heat to change the temperature of 5 g by 10°C?

	Specific Heat (in J g^{-1} °C^{-1})
$I_2(s)$	0.158
$H_2O(l)$	4.18
Au(s)	0.129
He(g)	5.19
Cu(s)	0.385

A $I_2(s)$

B $H_2O(l)$

***C** Au(s)

D He(g)

E Cu(s)

40 Let HA represent a weak monoprotic acid with $K_a = 1.0\times10^{-5}$. What is the pH at the equivalence point in the titration of 50.0 mL of 0.20 mol/L HA(aq) with 0.20 mol/L NaOH(aq)?

A 5.00

***B** 9.00

C 7.00

D 3.00

E 11.00

DATA SHEET
CHEM 13 NEWS EXAM 2010

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°C = 273.15 K

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