Name: ____________________ Student number: ______________

Chemistry 1A03 **Test 2** **Nov 13, 2015**

McMaster University **VERSION 1**

Instructors: D. Brock, G. Goward, A. Hitchcock, L. Davis

Duration: 120 minutes

This test contains 20 numbered pages printed on both sides. There are **30** multiple-choice questions appearing on pages numbered 3 to 17. Page 18 is extra space for rough work. Page 19 includes some useful data and equations, and there is a periodic table on page 20. You may tear off the last page to view the periodic table and the data provided.

You must enter your name and student number on this question sheet, as well as on the answer sheet. Your invigilator will be checking your student card for identification.
You are responsible for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

All questions are worth 2 marks - the total marks available are 60. There is **no** penalty for incorrect answers.
BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.
Instructions for entering multiple-choice answers are given on page 2.
SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION from the answers **(A)** through **(E). No work written on the question sheets will be marked**. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc.*) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 electronic calculators may be used; but they must NOT be transferred between students. Use of any aids other than those provided, is not allowed.

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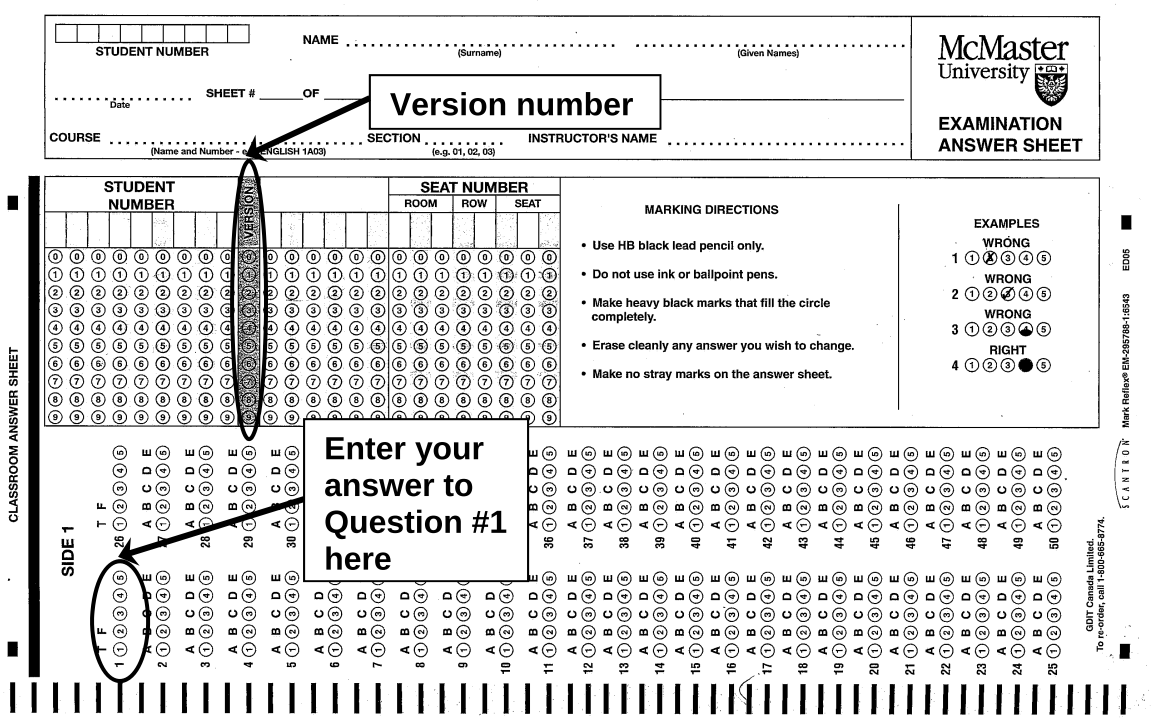
OMR EXAMINATION – STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUT EXAMINIATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.

The scanner, which reads the sheets, senses the bubble shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with an HB pencil. Marks made with a pen will **NOT** be sensed. Erasures must be thorough or the scanner will still sense a mark. Do **NOT** use correction fluid on the sheets. Do **NOT** put any unnecessary marks or writing on the sheet.

1. On SIDE 1 (**red side**) of the form, in the top box, *in pen*, print your student number, name, course name, and the date in the spaces provided. Then you **MUST** write your signature, in the space marked SIGNATURE.
2. In the second box, *with a pencil*, mark your student number and the **exam version number** in the space provided. If your student number does **NOT** begin with a 4, put "00" before your student number. <u>Then fill in the corresponding bubble numbers underneath</u>. Do not put in a leading zero when bubbling in your version number.
3. Answers: mark only **ONE** choice from the alternatives (A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the test paper.
4. Pay particular attention to the marking directions on the form.
5. Begin answering the question using the first set of bubbles, marked "1".



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1. What is the **pH** of a 0.0342 M solution of HCl?

   A) 1.466
   B) 4.456
   C) 7.568
   D) 3.492
   E) 1.081

HCl is a strong acid and therefore totally dissociates.
pH = −log $[H_3O^+]$ = −log (0.0342)
= 1.466

2. Which of the following statements about periodic trends are **TRUE**?

   i) The correct sequence for decreasing ionic radius is: $Br^- > Rb^+ > Sr^{2+}$.
   ii) The ground-state electron configuration of Si has no unpaired electrons.
   iii) The oxide of calcium is a basic oxide.
   iv) Rb loses electrons more easily than Na.
   v) The electronegativity of chlorine is smaller than that of phosphorus.

   A) ii, v
   B) i, iv
   C) iii, iv, v
   D) i, iii, iv
   E) i, ii, v

i) True. Since they are isoelectronic ions, radius decreases with increasing nuclear charge.
ii) False. Si = [Ne] $3s^2 3p^2$. Hund's rule state the electrons enter degenerate p orbitals with the same spin before pairing.
iii) True. Calcium is a metal. Metal oxides are basic.
iv) True. Ionization energy increases going up a group.
v) False. Electronegativity increases from left to right across a period.

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3. Which of the following statement(s) are **FALSE** ?

   i) Sodium has a larger first ionization energy than potassium.
   ii) Sodium has a larger atomic size than chlorine.
   iii) Oxygen has a larger first ionization energy than nitrogen.
   iv) Sulfur has a larger electronegativity than chlorine.

   A) ii, iv
   B) ii
   C) i, ii
   D) iii, iv
   E) i, iii

i) True. Ionization energy increases going up a group.Since they are isoelectronic ions, radius decreases with increasing nuclear charge.
ii) True. Atomic radius decreases from left to right across a period.
iii) False. Nitrogen has a half-filled subshell making it harder to ionize than O.
iv) False. Electronegativity increases from left to right across a period.

4. When preparing a 0.100 mol L^{-1} solution of NaOH, instead of weighing out 1.00 kg of NaOH and diluting it with the appropriate amount of water, the individual unknowingly used KOH by accident. How would this affect the **concentration** of the solution and the **volume** of base needed to titrate an acid?

	Concentration of Base Solution (relative to 0.100 mol L^{-1})	**Volume of base needed to reach equivalence point**
A)	more concentrated	more
B)	less concentrated	less
C)	more concentrated	less
D)	same concentration	same volume
E)	less concentrated	more

For 1.00 kg of NaOH, how much water is needed:

$$\frac{1000.\text{g}}{MM_{NaOH}} = \frac{1000.}{39.9969} = 25.0 \text{ mol}; \qquad C = \frac{n}{V}; \qquad 0.100\text{ M} = \frac{25.0}{V} \qquad V = 250.\text{ L}$$

If 1.00 kg of KOH, was added to the same volume of water the concentration would be:

$$\frac{1000.\text{g}}{MM_{KOH}} = \frac{1000.}{56.1049} = 17.824 \text{ mol}; \qquad C = \frac{n}{V} = \frac{17.824}{250.} = 0.0713\text{ M}$$

Therefore the base solution was less concentrated than 0.100 M and you would need more base solution to get the same number of moles of acid.

5. What is the **concentration (in mol L^{-1})** of an 8.00 mass % aqueous solution of NH_3, which has a density of 0.9651 g mL^{-1}?

A) 12.9
B) 4.53
C) 0.264
D) 7.55
E) 18.2

Assume 100. g of solution (You could assume any mass but this is convenient.)

Therefore m_{NH3} = 8.00 g

Volume of solution = 100. g/density = (100. / 0.9651) = 103.6162mL

$n_{NH3} = m_{NH3}/MM_{NH3}$ = 8.00/170.307 = 0.46973994 mol

$$C = \frac{n}{V} = \frac{0.46973994 \text{ mol}}{0.1036162 \text{ L}} = 4.53 \text{ M}$$

6. The threshold wavelength of photons that are able to eject electrons from Cesium metal is 500. nm. Which of the following statements are **FALSE**?

i) The energy of each photon of 500. nm light is 3.97×10^{-19} J.
ii) Shorter wavelengths of light will also eject electrons from Cesium.
iii) If ionization occurs, the number of electrons ejected is directly proportional to the brightness of the incident light.
iv) If the energy of the incident photons is doubled, the electron speed increases by a factor of four.
v) If the incident wavelength is tuned to 400. nm, the speed of the electrons is 8.67×10^5 ms^{-1}.

A) ii, v
B) i, iii
C) i, iv
D) iv, v
E) ii, iii

i) TRUE: For a photon $E = hc/\lambda$
ii) TRUE: Shorter wavelength is higher energy; $E = hc/\lambda$
iii) TRUE: Brightness of light is intensity or number of photons. Each photon can oly eject one electron. If electrons are ejected, More photons (brighter light) = more electrons ejected.
iv) FALSE: $E_{incident}$ = Threshold Energy + Kinetic Energy or $E_{incident}$ = Threshold Energy + ½mu^2
If you double the speed of the electron you would have 4 times the kinetic energy but there is no direct relationship between incident light and speed of the electron.
v) FALSE:

$$E_{incident} = hc/\lambda = \frac{(6.6256 \times 10^{-34})(2.9979 \times 10^{8})}{(400. \times 10^{-9})} = 4.9657 \times 10^{-19} \text{ J}$$

$$E_{threshold} = hc/\lambda = \frac{(6.6256 \times 10^{-34})(2.9979 \times 10^{8})}{(500. \times 10^{-9})} = 3.9726 \times 10^{-19} \text{ J}$$

$E_{incident}$ = Threshold Energy + ½mu^2
4.9657×10^{-19} J = 3.9726×10^{-19} J + ½$(9.109 \times 10^{-31})u^2$; $u = 4.67 \times 10^5$ ms^{-1}

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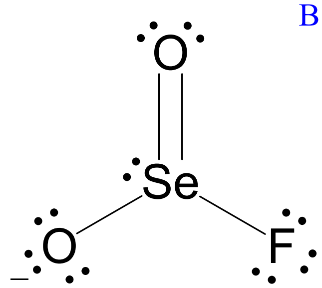
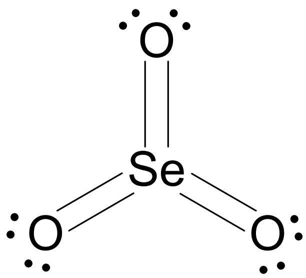
7. Rank the following species in **increasing terminal Se-O bond order** (from lowest to highest). (H atoms are attached to O)

SeO_2F^-, SeO_3, $HSeO_4^-$

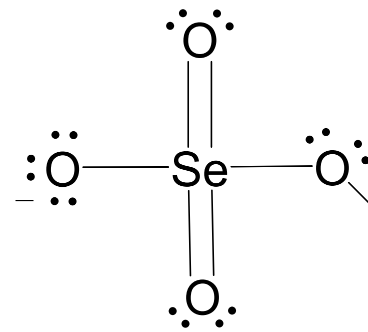
A) $HSeO_4^- < SeO_3 < SeO_2F^-$
B) $HSeO_4^- < SeO_2F^- < SeO_3$
C) $SeO_3 < SeO_2F^- < HSeO_4^-$
D) $SeO_2F^- < SeO_3 < HSeO_4^-$
E) $SeO_2F^- < HSeO_4^- < SeO_3$

B.O. = $\frac{2+1}{2}$ = 3/2





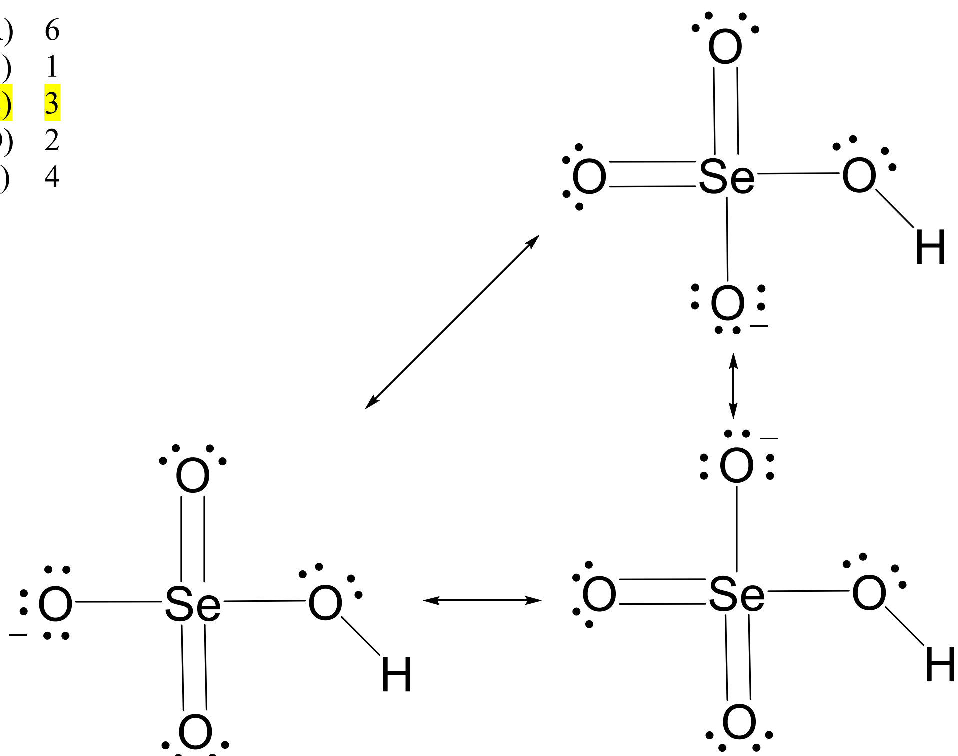
B.O. = 2



B.O. = $\frac{2+2+1}{3}$ = 5/3

8. How many **resonance structures** does $HSeO_4^-$ have? (H atom is attached to O)

A) 6
B) 1
C) 3
D) 2
E) 4



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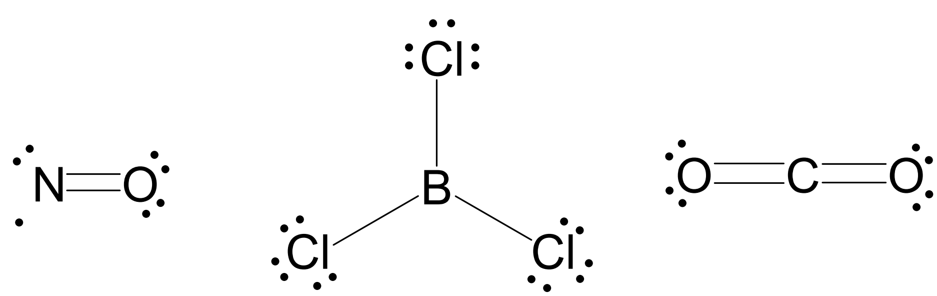
9. Which VSEPR class(es) would have **non-ideal** bond angles?

A) AX_4E_2 square planar: ideal
B) AX_3 trigonal planar: ideal
C) AX_2E_3 linear: ideal
D) AX_4E seesaw: non-ideal
E) More than one of the above.

10. Which of the following has an atom with **less than an octet**?

i) NO
ii) BCl_3
iii) CO_2

A) i, iii
B) i, ii
C) ii, iii
D) all of the above
E) none of the above



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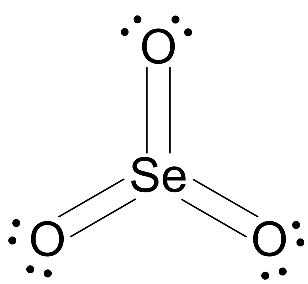
11. In class we discussed that methane clathrate ice is **unusual**. If water was frozen after exposing it to the following compounds, which compound would **MOST LIKELY** be found in the water lattice?

A) F_2
B) CH_2Cl_2
C) CO_2
D) SiO_2
E) O_2

CH_2Cl_2 is the only polar molecule. Because water is polar it is most likely to dissolve and crystallize polar compounds.

12. How many **non-bonding** electrons are there in SeO_3?

A) 14
B) 16
C) 12
D) 10
E) 18



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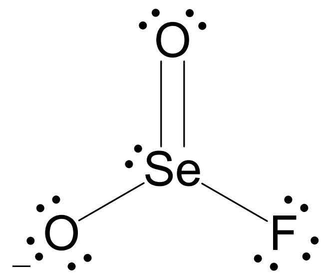
13. What is the **average formal charge** on the atoms in SeO_2F^-?

	Se	O	F
A)	0	−1	0
B)	+1	−1/2	0
C)	+1	−1	−1
D)	0	−1/2	0
E)	0	−1/3	−1/3



F.C. (Se) = 6 – 4 – 2 = 0
F.C. (F) = 7 – 1 – 6 = 0

F.C. (double bonded O) = 6 – 2 – 4 = 0
F.C. (single bonded O) = 6 – 1 – 6 = –1

Average Formal Charge (O) = $\frac{-1 + 0}{2}$ = –1/2

14. Which of the following perturbations will shift the given equilibrium **toward products**?

$$NO(g) + O_{3(g)} \rightleftharpoons NO_2(g) + O_2(g) \quad \Delta H = -200.8 \text{ kJ mol}^{-1}$$

i) The temperature is increased.
ii) Some NO_2 is removed from the reaction mixture.
iii) The reaction mixture is transferred to a vessel with twice the volume.
iv) The O_3 partial pressure is increased.
v) The total pressure is increased.

A) iii, v
B) i, iv
C) ii, iv
D) i, v
E) ii, iii

i) The reaction is exothermic so heat can be treated like a product. Increasing temperature is like adding products and will shift back to reactants.
ii) Removing a product will shift the reaction towards making more products.
iii) There are equal moles of gas on each side of the equation. Therefore changing volume will have no effect.
iv) Increasing reactants will shift the reaction towards making more products.
v) Increasing total pressure (by adding an inert gas for example) will have no effect on the equilibrium.

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15. AgCl(s) has a K_{sp} of 1.8×10^{-10}. Consider a system in which AgCl(s) is added to a solution of 1.0×10^{-3} M KCl. When equilibrium is established, what is the **concentration of Ag^{+}(aq)** in moles per litre?

A) 5.5×10^{-7}
B) 3.9×10^{-9}
C) 1.8×10^{-7}
D) 2.5×10^{-3}
E) 7.2×10^{-6}

	$AgCl(s) \rightleftharpoons$	$Ag^{+}(aq)$ +	$Cl^{-}(aq)$
I	Y	0	1.0×10^{-3} M
C	−x	+x	+x
E	Y−x	+x	1.0×10^{-3} M + x

$K_{sp} = [Ag^{+}][Cl^{-}] = 1.8 \times 10^{-10} = (1.0 \times 10^{-3}\text{ M} + x)(x)$

$x = 1.8 \times 10^{-7}$ M

16. **Persistant organic pollutants** are characterized by which of the following:

i) high vapour pressure
ii) resistance to chemical change
iii) large octanol-water partition coefficient
iv) high electron affinity
v) electron pair geometry

A) iv, v
B) ii, iii
C) i, iii
D) i, iv
E) ii, v

These are 2 of the 3 criteria for being a POP. The other is they must be toxic. See slide 10 on Day 2 of Unit 6.

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17. Which one of the following is **NOT** the correct form of the **equilibrium constant** for the given equilibrium?

A) $Cl_2(g) + 2Fe^{2+}(aq) \rightleftharpoons 2Cl^-(aq) + 2Fe^{3+}(aq)$ $\quad K = \dfrac{[Cl^-]^2[Fe^{3+}]^2}{P_{Cl_2}[Fe^{2+}]^2}$

B) $CaO(s) + H_2O(l) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$ $\quad K = \dfrac{[Ca^{2+}][OH^-]^2}{[H_2O]}$

C) $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$ $\quad K = P_{NH_3}P_{H_2S}$

D) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ $\quad K = P_{CO_2}$

E) $NO(g) + O_3(g) \rightleftharpoons NO_2(g) + O_2(g)$ $\quad K = \dfrac{P_{NO_2}P_{O_2}}{P_{NO}P_{O_3}}$

Liquids should not appear in the equilibrium expression.

18. Find the **equilibrium partial pressure of IBr,** for the equilibrium between:

$2IBr(g) \rightleftharpoons I_2(g) + Br_2(g)$

The initial pressure of IBr is 0.017 bar, and the value of K is 8.5×10^{-3}.

A) 0.081
B) 0.0055
C) 0.0094
D) 0.014
E) 0.0021

	$2IBr(g)$	$\rightleftharpoons$	$I_2(g)$	$+ Br_2(g)$
I	0.017		0	0
C	−2x		+x	+x
E	0.017−2x		+x	+x

$$K = \frac{P_{I2} \times P_{Br2}}{(P_{IBr})^2} = 8.5 \times 10^{-3} = \frac{(x)^2}{(0.017-2x)^2}$$

This is a perfect square, so square root both sides to simplify:

$$9.220 \times 10^{-2} = \frac{x}{0.017-2x}$$

$x = 1.3233 \times 10^{-3}$; Equilibrium pressure of IBr = 0.017−2x = 0.014

19. Determine the **molar solubility** of CaF_2. $K_{sp} = 3.45 \times 10^{-11}$

A) 2.38×10^{-2}
B) 1.69×10^{-3}
C) 2.05×10^{-4}
D) 4.25×10^{-8}
E) 8.43×10^{-4}

$$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$$

	$CaF_2(s)$	$Ca^{2+}(aq)$	$2F^-(aq)$
I	Y	0	0
C	−x	+x	+2x
E	Y−x	+x	+2x

$K_{sp} = [Ca^{2+}][F^-]^2 = 3.45 \times 10^{-11} = (x)(2x)^2$

$3.45 \times 10^{-11} = 4x^3$

$x = 2.05 \times 10^{-4}$

20. Which of the following set(s) of observations is/are **FALSE** for the reaction products of experiment #2, the cycles of copper.

i) $Cu(NO_3)_2$, aqueous
ii) $CuSO_4$, precipitate
iii) CuO, precipitate
iv) $Cu(OH)_2$, precipitate
v) NO_2, gas

A) iii, iv
B) ii
C) iv, v
D) iv
E) i, v

According to your solubility rules, $CuSO_4$ is soluble (see rule 6).

21. Consider the reaction between water vapour and carbon monoxide, where each are initially present a 1.0 bar. The value of *K* for the reaction at a certain temperature, T, is 0.63. What is the **equilibrium partial pressure of carbon dioxide** in bar?

$$H_2O(g) + CO(g) \rightleftharpoons CO_2(g) + H_2(g)$$

A) 0.59
B) 0.44
C) 0.25
D) 0.32
E) 0.67

	$H_2O(g)$	+ $CO(g)$ $\rightleftharpoons$	$CO_2(g)$	+ $H_2(g)$
I	1.0	1.0	0	0
C	−x	−x	+x	+x
E	1.0−x	1.0−x	+x	+x

$$K = \frac{P_{H2} \times P_{CO2}}{P_{H2O} \times P_{CO}} = 0.63 = \frac{(x)^2}{(1.0-x)^2}$$

This is a perfect square, so square root both sides to simplify:

$$0.793725 = \frac{x}{1.0-x}$$

x = 0.44 bar

22. Consider a weak acid, HA with $K_a = 1.0 \times 10^{-4}$. Which of the following is **FALSE** with respect to a 1.0 M solution of HA.

A) pK_b of the conjugate base = – log (10^{-10})
B) $[OH^-]$ in solution is 10^{-10} M
C) $K_a < [H_3O^+]$ in solution.
D) The small x approximation is valid when solving for the pH.
E) The conjugate base is a weak base.

A) True. $K_a \times K_b = K_w$ and $pK_b = -\log(K_b)$
B) False. See calcs.
C) True. See calcs.
D) True. $[HA]/K_a = 10000$ which is greater than 100.
E) True. Conjugate of a weak acid is a weak base.

	$HA(aq)$ + $H_2O(l)$ $\rightleftharpoons$	$H_3O^+(aq)$	+ $A^-(aq)$
I	1.0	0	0
C	−x	+x	+x
E	1.0−x	+x	+x

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = 1.0 \times 10^{-4} = \frac{(x)^2}{(1.0-x)}$$

Using the small x approximation, $x^2 = 1.0 \times 10^{-4}$

$[H_3O^+] = x = 1.0 \times 10^{-2}$ M

$[OH^-] = K_w / [H_3O^+] = 1.0 \times 10^{-14}\text{ M}/1.0 \times 10^{-2}$ M

$=1.0 \times 10^{-12}$ M

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23. Which of the following is **FALSE** with regard to acid strength?

A) $HF > HI$
B) $HBr > H_2S$
C) $HClO_3 > HClO_2$
D) $H_2SO_3 > H_3PO_3$
E) $H_2O > NH_3$

A) FALSE: Binary acid strength increases down a group. (And HI is a strong acid, HF is a weak acid)
B) TRUE: Binary acid strength increases across a row with increasing elecronegativity. (And HBr is a strong acid, H_2S is a weak acid)
C) TRUE: Oxyacids are stronger with more oxygens that stabilize anions by resonance.
D) TRUE: If Oxyacids have the same number of oxygens one needs to look at the inductive effect. S is more electronegative than P making H_2SO_3 a stronger acid than H_3PO_3.
B) TRUE: Binary acid strength increases across a row with increasing elecronegativity. (And H_2O is neutral and NH_3 is a weak base.)

24. What is the **pH** of a solution that is comprised of 2.0 L of water and 2.0 g of NaOCl? Ka [HOCl = 2.9×10^{-8}]

A) 5.26
B) 8.11
C) 8.59
D) 10.24
E) 9.83

Moles of NaOCl = mass / MM_{NaOCl} = 2.0 g / 74.4422 g mol^{-1}
= 0.026866 mol
[NaOCl] = 0.026866 mol / 2.0 L = 0.013433 M

	OCl^- (aq) + H_2O(l) $\rightleftharpoons$	HOCl(aq) +	OH^-(aq)
I	0.013433	0	0
C	−x	+x	+x
E	0.013433−x	+x	+x

$K_b = K_w / K_a = 1.0 \times 10^{-14} / 2.9 \times 10^{-8} = 3.4489 \times 10^{-7}$

$$K_b = \frac{[HOCl^+][OH^-]}{[OCl^-]} = 3.4489 \times 10^{-7} = \frac{(x)^2}{(0.013433-x)}$$

Using the small x approximation, $x^2 = 4.6329 \times 10^{-9}$
$[OH^-] = x = 6.80593 \times 10^{-5}$ M
$pOH = -\log[OH^-] = -\log(6.80593 \times 10^{-5}) = 4.17$
$pH = pK_w - pOH = 14.00 - 4.17 = 9.83$

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25. Determine the **FALSE** statement:

A) A Brønsted base is a proton acceptor.
B) H_2F^+ would be a strong acid.
C) 1 mole of $Mg(OH)_2$ would react with 2 moles of HCl to produce a neutral solution.
D) NH_4^+ is the conjugate acid of NH_3.
E) F^- is a Lewis acid

F^- has a complete octet and is one of the elements than cannot exceed an octet. Therefore it cannot accept electrons and therefore cannot be a Lewis acid.

26. If the pH of a solution is 12.100, what is the **concentration of OH^-** (mol L^{-1}) in the solution?

A) 0.106
B) 0.259
C) 0.0984
D) 0.0548
E) 0.0126

pOH = 14.000 – pH = 14.000 – 12.100 = 1.900

$[OH^-] = 10^{-pOH} = 10^{-1.900} = 0.0126$ M

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27. Determine the **FALSE** statement below.

A) NaH is a strong base.
B) When dissolved in water, CH_3NH_2 will produce OH^-.
C) When dissolved in water, ClOH would produce a solution with pH > 7.
D) Both HI and HCl are strong acids.
E) H_2CO_3 is not a strong acid

ClOH is the same molecule as HClO but shows the connectivity of the molecule. The molecules is hypochlorous acid (when dissolved in water). It dissociated into H_3O^+ and ClO^-, not Cl^+ and OH^-. It would then have an acidic pH (less than 7) not basic (greater than 7).

28. A solution of ethylamine ($CH_3CH_2NH_2$; $K_b = 4.30 \times 10^{-4}$) produces a pH = 12.67. What is the **% ionization** of the base?

A) 2.2 %
B) 0.054 %
C) 0.92 %
D) 0.0015%
E) 1.5 %

$pOH = pK_w - pH = 14.00 - 12.67 = 1.33$
$[OH^-] = 10^{-pOH} = 0.04677$ M

	$CH_3CH_2NH_2(aq) + H_2O(l) \rightleftharpoons$	$CH_3CH_2NH_3^+(aq)$	$+ OH^-(aq)$
I	Y	0	0
C	−x	+x	+x
E	Y−x	+x	+x

But $[OH^-] = x = 0.04677$ M

$$K_b = \frac{[CH_3CH_2NH_3^+][OH^-]}{[CH_3CH_2NH_2]} = 4.30 \times 10^{-4} = \frac{(x)^2}{(Y-x)} = \frac{(0.04677)^2}{(Y-0.04677\text{ M})}$$

Y = 5.1346 M
% ionization = 0.04677 / 5.1346 × 100% = 0.92%

 Continued on next page

29. When a particular gas expands against a constant external pressure of 2.50 atm, the volume increases by 9.75 L. During this transformation the gas also absorbs 1000. J of heat. What is the energy change, **Δ*U* (in kJ)**, for the gas?

A) +3.47
B) +4.39
C) –3.47
D) +1.47
E) –1.47

w = −PΔV; but P must be in kPa, so w = −(2.50)(101.325)(9.75) = −2469.8 J
the gas gains heat so q is positive

ΔU = q + w = +1000. J − 2469.8 J = −1.47 kJ

30. Which one of the following reactions has **no work done ON or BY** the system?

A) $2\ NO_2(g) + 7\ H_2(g) \rightarrow 2\ NH_3(g) + 4\ H_2O(l)$
B) $PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$
C) $Br_2(g) \rightarrow 2\ Br(g)$
D) $2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$
E) $N_2(g) + O_2(g) \rightarrow 2\ NO(g)$

For no work to be done on or by the system, the number of moles of gas must be the same on both sided of the equation.

Continued on next page

Extra space for rough work:

Name: ____________________ Student number: ______________

- **Some general data are provided on this page.**
- **A Periodic Table with atomic weights is provided on the next page.**

STP = 273.15 K, 1 atm
F = 96485 C/mol
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$c = 2.9979 \times 10^{8}$ m/s
$h = 6.6256 \times 10^{-34}$ Js
$m_e = 9.109 \times 10^{-31}$ kg
density(H_2O, l) = 1.00g/mL
$\Delta H^{o}_{vap}[H_2O] = 44.0$ kJ mol^{-1}
Specific heat of water = 4.184 J / g·°C
$R = 8.3145$ J K^{-1} mol^{-1} = 0.08206 L atm K^{-1} mol^{-1} = 0.083145 L bar K^{-1} mol^{-1}

1 bar = 100.00 kPa = 750.06 mm Hg = 0.98692 atm
0°C = 273.15 K
1 J = 1 kg m^2 s^{-2} = 1 kPa L = 1 Pa m^3
1 m = 10^6 µm = 10^9 nm = 10^{10} Å
1 cm^3 = 1 mL
1 g = 10^3 mg
1 Hz = 1 cycle/s

De Broglie wavelength:
$\lambda = h / mu = h / p$

Hydrogen atom energy levels:
$E_n = -R_H / n^2 = -2.179 \times 10^{-18}$ J / n^2
$KE = \frac{1}{2}mu^2$

Nernst Equation:

$$E = E° - \frac{RT}{zF}\ln Q \quad = E° - \frac{0.0257\ \text{V}}{z}\ln Q \quad = E° - \frac{0.0592\ \text{V}}{z}\log_{10} Q$$

Entropy change: $\Delta S = \frac{q_{rev}}{T}$

Solubility Guidelines for Common Ionic Solids

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations and the NH_4^+ cation are soluble . Except LiF and Li_2CO_3 which are insoluble.
2. Nitrates, acetates, bicarbonates, and perchlorates are soluble.
3. Salts of silver, lead and mercury (I) are insoluble. Except AgF which is soluble.
4. Fluorides, chlorides, bromides, and iodides are soluble. Except Group 2 fluorides which are insoluble
5. Carbonates, phosphates, chromates, sulfides, oxides, and hydroxides are insoluble. Except Group 2 sulfides and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} which are soluble.).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

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Name: ____________________ Student number: ______________

PERIODIC TABLE OF THE ELEMENTS

I 1	II 2	3	4	5	6	7	8	9	10	11	12	III 13	IV 14	V 15	VI 16	VII 17	VIII 18
		Transition Metals															
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.066	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 105.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra 226.03	89 **Ac 227.03	104 Unq [261]	105 Unp [262]	106 Unh [263]												

Atomic weights are based on $^{12}C = 12$ and conform to the 1987 IUPAC report values rounded to 5 significant digits.
Numbers in [ ] indicate the most stable isotope.

* Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
** Actinides	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	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 [262]

END OF EXAM