Last Name: **ID #** **# on the signature list:**
First Name: (to be entered by the teacher)

CHEMISTRY 205/4 Section Lec 51

ANSWERS TO MID TERM EXAMINATION Number of pages: 13
October 26, 2011 18:00 - 19:00

Instructor: G. DÉNÈS

Materials allowed:	Calculators with no storage capacity Printed translation dictionaries
Materials NOT allowed:	Books, notes Not your own periodic tables. One is attached to the questionnaire. No sharing of calculators No technical/scientific dictionary No electronic dictionary Not your own scrap paper. You will be provided with some.

INSTRUCTIONS:

1. This is a multiple choice examination.
2. Circle only one answer number for each question. There is only one correct answer for each question.
3. If you circle more than one answer number for a question, you will get a "zero" for that question.
4. If you have already circled an answer and you change your mind, erase the other answers, or clearly cross them out. Ambiguous answers will be counted as being wrong.
5. Only the circle around the question number will count. I will not read any calculation or anything else you may write on the questionnaire.
6. Do no write anything else on the front of the pages. Use the back of the questionnaire and/or the scrap paper you have been provided with for your calculations.
7. Answer every question.
8. All the questions are worth the same mark.
9. All group numbers used throughout this questionnaire are in the current official numbering system defined by the IUPAC.
10. When you are finished writing your exam, raise your hand and remain seated. The teacher or the invigilator will come to pick up your questionnaire and have you sign the attendance sheet, after checking your ID card. Do NOT leave your seat until the teacher allows you too.

Avogadro's number: 6.022×10^{23}

********** QUESTIONS START HERE **********

1. Tell which of the following statement is correct

1. A law is a well-tested, unifying principle, that explains a body of facts.
2. A theory is a well-tested, unifying principle, that explains a body of facts.
3. A theory is a concise statement of a behavior that seems to be the same under the same conditions.
4. A law is the same as a theory.
5. The color of a substance is a quantitative information

Answer # 2
Warning: A theory explains a body of facts, while a law does not.

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2. Tell which of the following has the smallest volume.

1. 100 g of oxygen (density = 0.00133 g/cm^3)
2. 500 g of ethanol (density = 0.789 g/cm^3)
3. 700 g of magnesium (density = 1.74 g/cm^3)
4. 800 g of sodium chloride (density = 2.16 g/cm^3)
5. 1,100 kg of aluminum (density = 2.70 g/cm^3)

Answer # 4
density = mass/volume => $\rho = m/V \Rightarrow V = m/\rho$

1. 100 g of oxygen (density = 0.00133 g/cm^3) => V = 100 g / 0.00133 g/cm^3 => V = 75200 cm^3
2. 500 g of ethanol (density = 0.789 g/cm^3) => V = 500 g / 0.789 g/cm^3 => V = 634 cm^3
3. 700 g of magnesium (density = 1.74 g/cm^3) =>V = 700 g / 1.74 g/cm^3 => V = 402 cm^3
4. 800 g of sodium chloride (density = 2.16 g/cm^3) => V = 800 g / 2.16 g/cm^3 => V = 370 cm^3
5. 1,100 kg of aluminum (density = 2.70 g/cm^3) => V = 1100000 g / 2.70 g/cm^3 => V = 407000 cm^3

The smallest volume is **370 cm^3 for 800 g of NaCl => Answer # 4**

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3. Tell which of the following statements is incorrect, regarding matter at ambient temperature:

1. In a gas, the particles are far apart and in constant motion.
2. In a liquid, the particles are arranged randomly and fairly close to one another .

3. In a solid, the particles are packed closely to one another and usually in a regular array.
4. In a solid, no motion of the particles is possible.
5. A liquid is a fluid.

Answer # 4 : In a solid, there is motion in the form of thermal vibrations, except at 0 K.

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4. Tell which of the following is not a potential energy:

1. Nuclear energy
2. Chemical energy
3. Thermal energy
4. Gravitational energy
5. Electrostatic energy

Answer # 3 : Thermal energy is due to the motion of atoms, molecules, or ions, at the particulate level, therefore, it is a **kinetic energy**, not a potential energy.

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5. Tell how many significant figures there are in the following number: 0.03205007500

1. 5
2. 8
3. 10
4. 11
5. 12

Answer # 3 All non-zeroes figures (larger font) are significant figures: 0.03205007500
All captive zeroes (larger font, in-between non-zero figures)
are significant figures: 0.03205007500
Since there is a decimal point, all trailing zeroes
(larger font, on the far right) are significant figures: 0.03205007500
Leading zeros (smaller font) are never significant figures: 0.03205007500
=> Significant figures are in larger font => **10 significant figure**s => **Answer # 3**

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6. Tell who is the scientist who related the volume of gases to the number of particles contained in the gas, regardless of which gas it is.

1. Gay-Lussac
2. Lavoisier
3. Dalton
4. Proust
5. Avogadro

Answer # 5 : it is Avogadro
Avogadro's hypothesis: At the same temperature and pressure, equal volumes of different gases contain the same number of particles.

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7. A reaction of 1 L of chlorine gas with 3 L of fluorine gas yields 2 L of a gaseous product. All gas volumes were measured at the same conditions of temperature and pressure. Give the formula of the gaseous product

1. ClF
2. Cl_2F_3
3. ClF_3
4. ClF_5
5. ClF_7

Answer # 3 : ClF_3
Use Avogadro's hypothesis
$1V(Cl_2) + 3V(F_2) \rightarrow 2V(product)$
$Cl_2 + 3\ F_2 \rightarrow$ 2 molecules of product, for a total of 2 Cl atoms and 6 F atoms : Lavoisier's law of conservation of mass + Dalton's atomic theory (chemical reactions involve reorganizing the way atoms are bound together; the atoms themselves are not changed)
2 Cl atoms + 6 F atoms $\rightarrow$ 2 molecules containing a total of 2 Cl atoms + 6 F atoms = $2\ ClF_3$
$Cl_2 + 3\ F_2 \rightarrow 2\ ClF_3$ (the reaction is balanced) => **The gaseous product is ClF_3.**

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8. An element is hard, malleable, loses electrons when it forms compounds, and it reacts very slowly with oxygen at ambient temperature. Tell which of the following categories it belongs to:

1. Group 1
2. Transition elements
3. Halogens
4. Chalcogens
5. Noble gases

Answer # 2 : transition elements

Let's examine the properties of the elements proposed

	Hard	Malleable	Loses e-	Reacts slowly with O_2 at RT
Group 1	No	No	Yes	rapid, except H_2, unless ignited
Transition elements	Yes	Yes	Yes	Slow for most, fast with none
Halogens	No	No	No	No, except F_2
Chalcogens	No	No	No	No
Noble gases	No	No	No	No

Only **transitions elements** have a "yes" answer to all properties => **Answer # 2**

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9. Tell which of the following discoveries was made by Rutherford:

1. Measurement of the charge of the electron
2. Measurement of the mass of the electron
3. Measurement of the charge/mass ratio of the electron
4. Discovery of radioactivity
5. Discovery of the atomic nucleus

Answer # 5 : Rutherford discovered the **atomic nucleus** by observing very high deflection of a small number of α−particles (a beam of He^{2+} ions from radioactive decay of uranium) by a metal sheet, and no/little deflection of most.

1. Measurement of the charge of the electron => Millikan
2. Measurement of the mass of the electron => calculated from e/m after e was measured
3. Measurement of the charge/mass ratio of the electron => Thomson
4. Discovery of radioactivity => Becquerel
5. Discovery of the atomic nucleus => Rutherford

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10. Bromine is a mixture of three isotopes. One of the isotopes has an atomic mass of 78.92 amu and has a relative abundance of 25.34 %. Another isotope has an atomic mass of 80.92 amu and a relative abundance of 24.66% . Tell what is the average atomic mass of the third isotope.

1. 79.89 amu
2. 78.52 amu
3. 79.26 amu

4. 80.23 amu
5. 80.97 amu

Answer # 1 : 79.89 amu
Isotope A: atomic mass of 78.92 amu and a relative abundance of 25.34 %
Isotope B: atomic mass of 80.92 amu and a relative abundance of 24.66%
Isotope C: atomic mass of X amu and a relative abundance of 100% - 25.34% - 24.66% = 50.00%
Average atomic mass = 79.90 amu (from the provided periodic table)

$$\text{Average atomic mass} = \text{sum of } \frac{\%\text{ abundance of isotope i}}{100} \times \text{mass of isotope i (i = 1, number of isotopes)}$$

$$79.90 \text{ amu} = \left(\frac{25.34\ \%}{100} \times 78.92 \text{ amu}\right) + \left(\frac{24.66\ \%}{100} \times 80.92 \text{ amu}\right) + \left(\frac{50.00\ \%}{100}\right) \times X \text{ amu}$$

79.90 amu = 19.998328 amu + 19.954872 amu + 0.5000 X amu
X amu = (79.90 amu - 19.998328 amu - 19.954872 amu) / 0.5000 => X = 79.8936 amu
X = 79.89 amu (4 significant figures) => Answer # 1

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11. Tell which is the formula of aluminum phosphide.

1. AlP
2. AlP_2
3. Al_2P
4. Al_2P_3
5. Al_3P_2

AlP => **Answer # 1**
Al is a metal, P is a non-metal => ionic compound

- ⇨ electronegativities: P > Al => Al gives a cation and P an anion
- ⇨ Al is group 13 with only one oxidation state, +3 (13-10) => Al^{3+}
- ⇨ Anion ends in "ide" and is in group 15 => no oxygen => P^{3-} (15-18)
- ⇨ Compounds are neutral Al^{3+} and P^{3-} in the ratio 1:1

=> **AlP** => **Answer # 1**

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12. Choose the correct name for $Mg(ClO_2)_2$

1. Magnesium chloride

2. Magnesium chlorate
3. Magnesium chlorite
4. Magnesium perchlorate
5. Magnesium hypochlorite

Answer # 3 => Magnesium chlorite
The name of the $[ClO_2]^-$ anion is "chlorite." With four oxygenated anions (1, 2, 3 or 4 oxygen atoms), the suffixes "ite" and "ate" with no prefix apply to the two "central" anions (i.e. with 2 and 3 oxygen atoms), and the central one with the least amount of oxygen (2) takes the "ite" suffix. Careful not to confuse "ite" with "ide", the latter has no oxygen.

1. Magnesium chloride $MgCl_2$
2. Magnesium chlorate $Mg(ClO_3)_2$
3. Magnesium chlorite $Mg(ClO_2)_2$
4. Magnesium perchlorate $Mg(ClO_4)_2$
5. Magnesium hypochlorite $Mg(ClO)_2$

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13. Give the name of $\mathbf{As_2O_5}$

1. Diarsenic pentoxide
2. Arsenic oxide
3. Arsenic pentoxide
4. Arsenic(II) oxide
5. Arsenic(V) oxide

Answer # 1 => Diarsenic pentoxide
Both As and O are non-metals => molecular compound (covalent bonding)
Roman numerals are used in ionic compounds only => Not answers 4 or 5
Prefixes used to indicate the number of atoms of each element in the formula => **diarsenic pentoxide**
=> Answer # 1

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14. Tell what is the oxidation number of Cr in CrAs.

1. 1
2. 2
3. 3

4. 4
5. 6

Answer # 3 => Cr(III), oxidation number +3
Cr is a transition metal, As is a non-metal => Electronegativity scale: As > Cr
=> As gives an anion, Cr gives a cation
As is in group 15 => 15-18 = -3 oxidation number
Since compounds are neutral, **Cr must have the +3 oxidation number**.

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15. Determine the molar mass of sodium sulfate

1. 164.2 g/mol
2. 242.1 g/mol
3. 126.3 g/mol
4. 149.8 g/mol
5. 142.0 g/mol

Answer # 5 => 142.0 g/mol
The sulfate ion is $[SO_4]^{2-}$
Na is in group 1 => Na^+
Since compounds are neutral, the formula of sodium sulfate is Na_2SO_4.
The molar mass is the sum of all the atomic masses contained in the formula:
$M[Na_2SO_4] = [2 \times M(Na)] + M(S) + [4 \times M(O)]$
$M[Na_2SO_4] = [2 \times 22.99] + 32.07 + [4 \times 15.999] = 142.046$ g/mol = **142.0 g/mol** (4 significant figures)

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16. In 1987, the first substance to act as a superconductor at a temperature above that of liquid nitrogen (77 K) was discovered. Its percent composition by mass is the following:
Y: 13.35 % Ba: 41.22 % Cu: 28.62 % O: 16.81 %
Tell what is its chemical formula.

1. $YBa_3Cu_2O_7$
2. $YBa_2Cu_3O_6$
3. $Y_2Ba_2Cu_2O_6$
4. YBa_4CuO_6
5. $YBa_2Cu_3O_7$

Answer # 5 => $YBa_2Cu_3O_7$

The percent composition by mass is the mass *m* of each element contained in 100 g of compound.
1. Determine the number of moles *n* of each element in 100 g of compound using the formula $n = m/M$.

$$n(Y) = \frac{13.35\ g}{88.91\ g/mol} = 0.15015\ mol\ Y \qquad n(Ba) = \frac{41.22\ g}{137.33\ g/mol} = 0.3002\ mol\ Ba$$

$$n(Cu) = \frac{28.62\ g}{63.55\ g/mol} = 0.4504\ mol\ Cu \qquad n(O) = \frac{16.81\ g}{15.999\ g/mol} = 1.0507\ mol\ O$$

2. Divide the number of moles of each element by the smallest, i.e. by n(Y) = 0.15015

$$\frac{n(Y)}{n(Y)} = 1 \qquad \frac{n(Ba)}{n(Y)} = \frac{0.30002}{0.15015} = 1.9993 \approx 2$$

$$\frac{n(Cu)}{n(Y)} = \frac{0.4504}{0.15015} = 2.9997 \approx 3 \qquad \frac{n(O)}{n(Y)} = \frac{1.0507}{0.15015} = 6.9998 \approx 7$$

For each Y atom there are 2 Ba atoms, 3 Cu atoms and 7 O atoms
The formula is **$YBa_2Cu_3O_7$ => Answer # 5**

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17. Balance the following equation and give the coefficient of O_2 in the balanced equation

$$C_6H_5CH_3\ (l) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (l)$$

1. 3
2. 4
3. 6
4. 9
5. 12

Answer # 4 => 9 O_2 *(g)*

$$C_6H_5CH_3\ (l) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (l)$$

Balance O last since it is contained in two products.

Balance C : $C_6H_5CH_3\ (l) + O_2\ (g) \rightarrow 7\ CO_2\ (g) + H_2O\ (l)$

Balance H : $C_6H_5CH_3\ (l) + O_2\ (g) \rightarrow 7\ CO_2\ (g) + 4\ H_2O\ (l)$

Balance O : $C_6H_5CH_3\ (l) + 9\ O_2\ (g) \rightarrow 7\ CO_2\ (g) + 4\ H_2O\ (l)$

Checking: 7 C, 8 H, 18 O 7 C, 8 H, 18 O

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18. When aqueous solutions of sodium chloride and ammonium nitrate are mixed together, tell what happens.

1. An acid base reaction takes place
2. A redox reaction takes place
3. No precipitation takes place
4. Sodium nitrate precipitates
5. Ammonium chloride precipitates

Answer # 3 => No precipitation takes place
Mixing aqueous solutions of the two salts will give a solution containing the four hydrated ions: $Na^+(aq)$, $Cl^-(aq)$, $NH_4^+(aq)$, and $NO_3^-(aq)$.

1. An acid base reaction takes place : No (No acid (H^+ donor) or base (OH^- donor / H^+ acceptor))
2. A redox reaction takes place : No (No change of oxidation number takes place)
3. No precipitation takes place : Correct (Exchanging partners would give sodium nitrate and ammonium chloride, both of which are soluble => No precipitation takes place)
4. Sodium nitrate precipitates => No, it is soluble
5. Ammonium chloride precipitates => No, it is soluble

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19. Tell which of the following compounds is a <u>mixed-oxidation state</u> compound:

1. SnO
2. SnO_2
3. SnF_4

4. SnF_2
5. Sn_3F_8

Answer = 5 => Sn_3F_8

Possible oxidation states: Sn: +2 (suboxidation state) and +4 (full oxidation state) (group 14 => 14-10 = +4)
O: -2 (group 16 => 16 – 18 = -2)
F: -1 (group 17 => 17 – 18 = -1)
The sum of the oxidation states of all elements must be zero in a compound.
Mixed-oxidation state compounds contain the same element (here Sn) in more than one oxidation states.

1. SnO : -2 for O => +2 for Sn => Allowed => Not a mixed oxidation state compound
2. SnO_2 -2 for O => +4 for Sn => Allowed => Not a mixed oxidation state compound
3. SnF_4 -1 for F => +4 for Sn => Allowed => Not a mixed oxidation state compound
4. SnF_2 -1 for F => +2 for Sn => Allowed => Not a mixed oxidation state compound
5. Sn_3F_8 -1 for F => +8/3 for Sn => Not integer => Not allowed
   => Sn_3F_8 is the mixed oxidation state compound $Sn(II)_2Sn(IV)F_8$ => **Answer = 5**

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20. Potassium dichromate reacts with ethanol in aqueous acidic medium according to the following unbalanced equation:

$$Cr_2O_7^{2-}(aq) + C_2H_5OH\ (l) \rightarrow Cr^{3+}(aq) + CO_2(g)$$

Balance the equation and give the stoichiometric coefficient of H_2O in the balanced equation.

1. 5
2. 6
3. 10
4. 11
5. 12

Answer # 4 => 11 H_2O

Change of oxidation number: Cr : +6 to +3 => requires 3 e- / Cr
C : -2 to +4 => gives 6 e- / C

Reduction half reaction Oxidation half reaction

$Cr_2O_7^{2-}(aq) \rightarrow Cr^{3+}(aq)$ $\quad$ $C_2H_5OH\ (l) \rightarrow CO_2(g)$

1) Balancing elements others than O and H:

$Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq)$ $\quad$ $C_2H_5OH\ (l) \rightarrow 2\ CO_2(g)$

2) Balancing O by adding H_2O :

$Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$ $\quad$ $3\ H_2O(l) + C_2H_5OH\ (l) \rightarrow 2\ CO_2(g)$

3) Balancing H by adding H^+ :

$14\ H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O$ $\quad$ $3\ H_2O(l) + C_2H_5OH\ (l) \rightarrow 2\ CO_2(g) + 12\ H^+(aq)$

4) Balancing charges by adding electrons (e^-) :

$6\ e^- + 14\ H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O$ $\quad$ $3\ H_2O(l) + C_2H_5OH\ (l) \rightarrow 2\ CO_2(g) + 12\ H^+(aq) + 12\ e^-$

5) Checking that the number of electrons used is the same as required :

$6\ e^- + 14\ H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2\ Cr^{3+}(aq) + 7\ H_2O$ $\quad$ $3\ H_2O(l) + C_2H_5OH\ (l) \rightarrow 2\ CO_2(g) + 12\ H^+(aq) + 12\ e^-$

$6\ e^-$ required for 2 Cr => 3 e^-/Cr as expected $\quad$ $12\ e^-$ given off for 2 C => 6 e^-/C as expected

6) Multiplying the reduction half reaction by 2 in order to have the same number of electrons in both half reactions :

$12\ e^- + 28\ H^+(aq) + 2\ Cr_2O_7^{2-}(aq) \rightarrow 4\ Cr^{3+}(aq) + 14\ H_2O$

$3\ H_2O(l) + C_2H_5OH\ (l) \rightarrow 2\ CO_2(g) + 12\ H^+(aq) + 12\ e^-$

6) Adding the two half reactions together :

$12\ e^- + 28\ H^+(aq) + 2\ Cr_2O_7^{2-}(aq) + 3\ H_2O(l) + C_2H_5OH\ (l) \rightarrow 4\ Cr^{3+}(aq) + 14\ H_2O + 2\ CO_2(g) + 12\ H^+(aq) + 12\ e^-$

7) Simplifying electrons, H^+ and H_2O :

$16\ H^+(aq) + 2\ Cr_2O_7^{2-}(aq) + C_2H_5OH\ (l) \rightarrow 4\ Cr^{3+}(aq) + 11\ H_2O + 2\ CO_2(g)$

8) Checking for further simplifications/changes:

- H^+ remains since the reaction takes place in acidic medium;
- no common divisor of stoichiometric coefficients => no further simplification is possible.

9) Checking that the reaction is balanced for elements and charges :

$16\ H^+(aq) + 2\ Cr_2O_7^{2-}(aq) + C_2H_5OH\ (l) \rightarrow 4\ Cr^{3+}(aq) + 11\ H_2O + 2\ CO_2(g)$

22 H, 4 Cr, 2 C, 15 O, 12 + $\quad$ 22 H, 4 Cr, 2 C, 15 O, 12 +

=> The reaction is balanced, **the stoichiometric coefficient of H_2O is 11 => Answer # 4**