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

CHEMISTRY 205/4 Section Lec 03

ANSWERS TO MID TERM EXAMINATION

Number of pages: 7

February 15, 2011 8:45 - 9:45am

Instructor: G. DÉNÈS

VERY IMPORTANT: Choose only one answer number for each question. There is only one correct answer for each question.
Answer on both the blue Scantron sheet by shading in pencil the answer number and on this questionnaire by circling the answer number. If you give a different answer on the Scantron sheet and the questionnaire for the same question, the answer number on the Scantron sheet will count.

Materials allowed: Calculators with no storage capacity
Printed translation dictionaries

Materials NOT allowed: Books, notes
Periodic tables
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. Choose only one answer number for each question. There is only one correct answer for each question. Answer on both the blue Scantron sheet by shading the answer number and on this questionnaire by circling the answer number. If you give a different answer on the Scantron sheet and the questionnaire for the same question, the answer number on the Scantron sheet will count.

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.

A

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}

Average atomic masses per mole: See the periodic table on the last sheet

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

1. As part of a lab assignment to determine the value of the ideal gas constant (*R*), a student measured the pressure (*P*), the volume (*V*), and the temperature (*T*) of one mole of gas. These parameters are related by the following equation:

$$R = \frac{p\,V}{n\,T}$$ where *n* is the number of moles and the temperature *T* is in kelvins

The following parameters were obtained for $n = 1.00$ mol, $p = 2.560$ atm, $V = 8.8$ L and $T = 2\ ^{o}C$.

Calculate *R* with the correct number of significant figures (do not worry about the unit of the result for now)

a. 0.0819
b. 0.082
c. 0.08188
d. 11.26
e. 11

Answer b: 0.082

T is in kelvins => $T = 2\ ^{o}C. \times \frac{1\ K}{1\ ^{o}C} + 273.15\ K = 275.15\ K$

$$R = \frac{p\,V}{n\,T} = \frac{2.560 \times 8.8}{1.00 \times 275.15} = 0.081875341 = \mathbf{0.082}$$ (2 significant figures like 8.8)

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2. Tell what is the unit of R in the above question

a. $L.atm^{-1}.mol.\ K^{-1}$
b. $Mol.^{o}C\ .L^{-1}.at^{-1}$
c. $Mol.K.L^{-1}.at^{-1}$
d. $L.atm.mol^{-1}.^{o}C$
e. $L.atm.mol^{-1}.K^{-1}$

Answer e. $\mathbf{L.atm.mol^{-1}.K^{-1}}$

$$R = \frac{p\,V}{n\,T} = \frac{V\,p}{n\,T} \text{ in units } \frac{L.atm}{mol.K} = \mathbf{L.atm.mol^{-1}.K^{-1}}$$

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3. When water boils, bubbles rise to the surface. Tell what is contained in the bubbles.

a. Air
b. A mixture of hydrogen gas and oxygen gas
c. A mixture of nitrogen gas and oxygen gas
d. Water vapor
e. Carbon dioxide

Answer d. Water vapor

When water boils, fast <u>vaporization</u> takes place**.** Vaporization is the ***liquid to gas*** <u>change of physical state</u>, therefore the bubbles contain water vapor. This is a <u>physical transformation</u>.

A mixture of hydrogen gas and oxygen gas is a chemical transformation, that requires chemical methods, such as ***electrolysis***.

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4. Tell which of the following statements is **incorrect**:

a. *Chromatography* is a chemical method of separation
b. On a non-foggy day, *air* is a homogeneous mixture
c. *Compounds* can be decomposed to elements by use of chemical methods
d. *Compounds* can be separated from mixtures by use of distillation
e. *Sublimation* is the physical change from solid to gas

Answer a. *Chromatography* is NOT a chemical method of separation

Chromatography is a chemical method of separation is incorrect. It is a **physical method of separation**.

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5. Mercury (Hg) poisoning is a debilitating disease that is often fatal. A lake is found to contain 0.4 μg Hg/mL of water. The lake has a surface area of 100 mi^2 and an average depth of 20 ft. What is the total mass of mercury in the lake? Conversion factors are the following:

1 mi = 1760 yd	1 inch = 2.54 cm	1 L = 1 dm^3
1 m = 1.094 yd	1 ft = 12 inch	

a. $3 * 10^6$ kg
b. 6 000 kg
c. $6 * 10^5$ kg
d. 6 kg
e. $3 * 10^3$ kg

Answer: c. $6 * 10^5$ kg

The amount of mercury in the lake is given in μg Hg/mL of water, i.e. in mass by unit of volume (mL) of water, therefore the volume of the lake must be calculated. First, the relationship between the unit of volume in mL and unit of length must be established since Volume = $(\text{Length})^3$.

$1 \text{ L} = 1 \times 10^3 \text{ mL} \Rightarrow 1 \text{ mL} = 1 \times 10^{-3} \text{ L}$

$$1\ \text{dm} = \frac{1 \times 10^{-1}\ \text{m}}{1\ \text{dm}} \times \frac{1 \times 10^{2}\ \text{cm}}{1\ \text{m}} = 10\ \text{cm} \Rightarrow 1\ \text{dm}^3 = (10\ \text{cm})^3 = 1 \times 10^3\ \text{cm}^3$$

$$\frac{1\ \text{L}}{1\ \text{dm}^3} = \frac{1 \times 10^3\ \text{mL}}{1 \times 10^3\ \text{cm}^3} = \frac{1\ \text{mL}}{1\ \text{cm}^3} \Rightarrow 1\ \text{mL} = 1\ \text{cm}^3$$ since 1 L = 1 dm^3 by definition of the liter.

Volume = Surface area (given in mi^2) x depth (given in ft)

$$1\ \text{mi} = \frac{1760\ \text{yd}}{1\ \text{mi}} \times \frac{1\ \text{m}}{1.094\ \text{yd}} \times \frac{1 \times 10^{2}\ \text{cm}}{1\ \text{m}} = 1.608775 \times 10^5\ \text{cm}$$

$$\Rightarrow 100\ \text{mi}^2 = 100 \times \frac{(1.608775 \times 10^5\ \text{cm})^2}{1\ \text{mi}^2} = 2.588157 \times 10^{12}\ \text{cm}^2 = S\ \text{(Surface area)}$$

$$1\ \text{ft} = \frac{12\ \text{in}}{1\ \text{ft}} \times \frac{2.54\ \text{cm}}{1\ \text{in}} = 30.48\ \text{cm}$$

$$\Rightarrow 20\ \text{ft} = 20 \times \frac{30.48\ \text{cm}}{1\ \text{ft}} = 609.6\ \text{cm} = D\ \text{(Depth)}$$

Volume $V = S \times D = 2.588157 \times 10^{12}\ \text{cm}^2 \times 609.6\ \text{cm} = 1.5766017 \times 10^{15}\ \text{cm}^3$

$$\text{Mass(Hg)} = \frac{0.4\ \mu\text{g}}{1\ \text{mL}} \times \frac{1\ \text{mL}}{1\ \text{cm}^3} \times 1.5766017 \times 10^{15}\ \text{cm}^3 = 6.3064 \times 10^{14}\ \mu\text{g}$$

$$6.3064 \times 10^{14}\ \mu\text{g} \times \frac{1 \times 10^{-6}\ \text{g}}{1\ \mu\text{g}} \times \frac{1\ \text{kg}}{1 \times 10^{3}\ \text{g}} = 6.306 \times 10^5\ \text{kg} \Rightarrow 6 \times 10^5\ \text{kg}$$ (1 significant figure, since 0.4 μg Hg/mL has only one significant figure)

=> The answer is **6×10^5 kg (answer c)**

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6. Tell which of the following statements of Dalton's atomic theory is in disagreement with the existence of isotopes:

1. Each element is made of tiny particles called "atoms."
2. The atoms of a given element are identical: the atoms of a different elements are different in some fundamental way.
3. Chemical compounds are formed when atoms combine with each other. A given compound always has the same relative numbers and types of atoms.
4. Chemical reactions involve reorganization of the atoms - changes in the way they are combined. The atoms themselves are not changed in a chemical reaction

a. Statement number 1
b. Statement number 2
c. Statement number 3
d. Statement number 4
e. None of the above statements

Answer: b. Statement number 2

2. The atoms of a given element are identical: They are **NOT** completely identical: isotopes of different elements have a ***different number of neutrons***. However, since neutrons do not have a direct influence on chemical properties, Dalton's statement made perfect sense.

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7. Give the name of the physical transformation from gas to liquid:

a. Sublimation
b. Liquefaction
c. Melting
d. Solidification
e. Vaporization

Answer: b. *Liquefaction*

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8. In tin(IV) oxide, there is twice as much oxygen in mass per gram of tin than there is in tin(II) oxide. Tell which law the above statement corresponds to.

a. Avogadro's law
b. Law of definite proportions
c. Law of conservation of mass
d. Law of multiple proportions
e. Atomic theory

Answer: d. *Law of multiple proportions*
The law of multiple proportions is concerned with several compounds containing the same elements. This is not to be confused with the law of definite proportions that deals with one compound only.

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9. Tell who measured the charge of the electron.

a. Thomson
b. Rutherford
c. Becquerel
d. Millikan
e. Franklin

Answer: d. *Millikan*

Thomson discovered the existence of the electron, and he measured the mass/charge ratio, however, he did not measured its charge. Millikan did, by measuring the electric field required to stop the fall of electrically charged fine droplets of oil.

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10. Tell which of the following radiation(s) is(are) deviated from their original path by a magnetic field.

a. α- radiation only
b. β- radiation only
c. γ- radiation only
d. α- and β- radiations
e. β- and γ-radiations

Answer: d. *α- and β- radiations*

Electrically charged particles in motion create a magnetic field, which interacts with the applied magnetic field, thereby making the charged particles being deviated by an applied magnetic field.

α-particles are He^{2+} ions and are therefore electrically charged

β-particles are fast electrons and are therefore electrically charged

γ-particles are photons (electromagnetic radiation) and therefore have no electrical charge

=> ***Only α- and β- radiations are charged and are therefore deviated by a magnetic field***

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11. An atom of an element has 45 neutrons and 35 protons. Give the name of the group this element belongs to.

a. Halogens
b. Chalcogens
c. Alkaline earth metals
d. Noble gases
e. Alkali metals

Answer: a. *Halogens*

The number of protons determines the atomic number *Z* and therefore determines the group number

Groups →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Periods																		
1	1																	2
2	3	4											5	6	7	8	9	10
3	11	12											13	14	15	16	17	18
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	

Looking at the periodic table, *Z* = 35 is in group 17 => ***Halogens***

Note: The umber of neutrons was not needed to answer the question.

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12. Rhenium (Re) is a transition metal that is a mixture of two isotopes. One of the isotopes has an atomic mass of 184.9530 amu and has a relative abundance of 37.400 %. Determine the atomic mass of the second isotope.

a. 185.83 amu
b. 185.91 amu
c. 186.67 amu

d. 186.96 amu
e. 187.57 amu

Answer: d. *186.96 amu*

Isotope 1: m_1 = 184.9530 amu, relative abundance A_1 = 37.400 %
Isotope 2: m_2 = ? amu, relative abundance A_2 = ? %
Average atomic mass m_{av} = 186.21 amu (from the periodic table)

$A_1 + A_2 = 100\ \% \Rightarrow A_2 = 100\ \% - A_1 = 100\ \% - 37.400\ \% = 62.600\ \%$
Let's define F_1 and F_2 the *fractional abundance* of each isotope, where
fractional abundance = relative abundance in % / 100 => F_1 = 0.37400 and F_2 = 0.62600
$m_{av} = (m_1 . F_1) + (m_2 . F_2)$
$(m_2 . F_2) = m_{av} - (m_1 . F_1)$

$$m_2 = \frac{m_{av} - (m_1 . F_1)}{F_2} = \frac{186.21 \text{ amu} - (184.9530 \text{ amu} \times 0.37400)}{0.62600} \text{ with } \frac{5 \text{ sig. fig.}}{5 \text{ sig. fig.}}$$

m_2 = 186.9609872 => ***m_2 = 186.96 amu*** with 5 significant figures

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13. Choose the correct names of Cu_2O.

a. Copper(I) oxide and cuprous oxide
b. Copper(II) oxide and cuprous oxide
c. Copper(II) oxide and cupric oxide
d. Copper(I) oxide and cupric oxide
e. Dicopper monoxide

Answer: a. *Copper(I) oxide and cuprous oxide*

Cu is a metal, O is a non-metal => Cu_2O is an ionic compound => No prefixes to be used in the name => answer e is incorrect
Cu is a transition metal => the oxidation state of the metal Cu is given in Roman numerals between parentheses.
O is in group 16 => charge of the oxide ion is 16-18 = -2
Since the compound is neutral, Cu_2 has a charge of +2 => +1 for each Cu => Cu(I) => Copper(I) oxide
Copper(I) oxide is Cu_2O and copper(II) oxide is CuO (Cu is +2, O is -2 => compound is neutral)
Suffix "ous" applies to the compound containing the least amount of O per Cu: O/Cu = ½ = 0.5 in Cu_2O
Suffix "ic" applies to the compound containing the highest amount of O per Cu: O/Cu = 1/1= 1 in CuO
=> Cu_2O is ***Copper(I) oxide and cuprous oxide***

Note: You didn't need to know that CuO is the other copper oxide. Since, in Cu_2O, copper has the +1 oxidation number, it had to be the lowest, therefore "cuprous", since in a single atom metal ion, electrons are exchanged in whole and thus oxidation numbers lower than +1 are not possible.

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14. Choose the correct name of $\mathbf{P_2O_3}$ according to the current official rule of nomenclature.

a. Phosphorus(III) oxide
b. Phosphorus(III) trioxide
c. Phosphorus(II) oxide
d. Phosphorus(II) trioxide
e. Diphosphorus trioxide

Answer: e. Diphosphorus trioxide

Both phosphorus and oxygen are non-metals, therefore bonding is covalent. Therefore, oxidation states in Roman numerals, used only for metals, with ionic bonding, should not be used here. Prefixes should be used to give the number of atoms of each kind.

=> P_2O_3 is ***Diphosphorus trioxide***

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15. Give the number of elementary particles in the gadolinium ion $\mathbf{^{158}Gd^{3+}}$. Note: gadolinium is a rare earth.

a. 61 electrons, 64 protons, 158 neutrons
b. 64 electrons, 67 protons, 94 neutrons
c. 61 electrons, 64 protons, 94 neutrons
d. 64 electrons, 67 protons, 91 neutrons
e. 64 electrons, 61 protons, 158 neutrons

Answer: c. 61 electrons, 64 protons, 94 neutrons

Periodic table => for Gd, Z = 64 => 64 protons (definition of *atomic number Z*)
In Gd^{3+} => 3+ charge means: number of electrons = number of protons - 3 = Z - 3 = 64 - 3 = 61 electrons
Atomic mass A = number of neutrons N + number of protons Z
A = N + Z => N = A - Z = 158 - 64 = 94 neutrons

=> $^{158}Gd^{3+}$ contains ***61 electrons, 64 protons, 94 neutrons***

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16. Tell which of the following compound(s) is/are <u>(a) mixed oxidation states</u> compound(s)

a. PbO only
b. PbO_2 only
c. Pb_2O_3 only
d. Pb_3O_4 only
e. Pb_2O_3 and Pb_3O_4

Answer: **e.** **Pb_2O_3 and Pb_3O_4**

A *mixed oxidation state compound* contains the same element in more than one oxidation state.
Lead Pb belongs to group 14, and can therefore have the +4 and +2 oxidation numbers in its compounds.
Oxygen belongs to group 16, and has therefore the 16-18 = -2 oxidation number.
The sum of the oxidations numbers ON of all atoms in a compound is equal to zero since compounds are neutral.
In a lead oxide: ON(all Pb) + ON(all O) = 0 => ON(all Pb) = 0 - ON(all O)

$$\Rightarrow ON(Pb) = \frac{ON(\text{all } Pb)}{\text{Number of } Pb}$$

PbO : ON(Pb) = 0 - (-2) = +2 => Allowed => Not a mixed oxidation states compound
PbO_2 : ON(Pb) = 0 - (-2 x 2) = +4 => Allowed => Not a mixed oxidation states compound
Pb_2O_3 : [2 x ON(Pb)] = 0 - (-2 x 3) = +6 => ON(Pb) = +6/2 = +3 Not allowed =>
Pb_2O_3 is **$Pb(II)Pb(IV)O_3$** => It is a mixed oxidation states compound
Pb_3O_4 : [3 x ON(Pb)] = 0 - (-2 x 4) = +8 => ON(Pb) = +8/3 = +2.67 Not allowed =>
Pb_3O_4 is **$Pb(II)_2Pb(IV)O_3$** => It is a mixed oxidation states compound
= Both **Pb_2O_3 and Pb_3O_4** are mixed oxidation states compounds

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A

17. An element is a gas at ambient conditions of temperature and pressure. Choose the answer that describes it best.

a. It is a metalloid and it will preferentially form covalent bonding
b. It is a non-metal and it will preferentially form covalent bonding or anions
c. It is a noble gas
d. It is a transition metal
e. It is an alkali metal

Answers: **b.** **It is a non-metal and it will preferentially form covalent bonding or anions**
c. **It is a noble gas**

There were two correct answers. Either one gave the full mark

All metalloids (B, Si, Ge, As and Te) are solids at ambient conditions => Not answer *a*.
Non-metals H, O, F, Cl and all noble gases are gases at ambient conditions, and O, F and Cl preferentially form covalent bonding or anions => **Answer *b* is correct.**
All noble gases are gases at ambient conditions => **Answer *c* is correct.**
All transition metals and all alkali metals are solids at ambient conditions => Not answers *d* or *e*.

= > **Only answers *b* and *c* are correct**

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18. For calcium carbonate, determine the molar mass, the number of moles and the number of unit formulas in 10.000g.

a.	100.1 g/mol	7.763×10^{-2} mol	4.675×10^{22} unit formulas
b.	100.1 g/mol	9.991×10^{-2} mol	6.017×10^{22} unit formulas
c.	68.09 g/mol	1.664×10^{-2} mol	1.002×10^{23} unit formulas
d.	100.1 g/mol	$9.991 \times 10^{+2}$ mol	6.017×10^{24} unit formulas
e.	68.09 g/mol	$1.664 \times 10^{+2}$ mol	6.017×10^{24} unit formulas

Answer: **b.** **100.1 g/mol** **9.991×10^{-2} mol** **6.017×10^{22} unit formulas**

The formula of calcium carbonate is $CaCO_3$ (Ca makes Ca^{2+} since it is in group 2; the carbonate ion is $(CO_3)^{2-}$.
Molar mass = M[Ca] + M[C] + (3 x M[O]) = 40.08 g/mol + 12.01 g/mol + (3 x 15.999 g/mol)
Molar mass = 100.087 g/mol => ***M* = 100.1 g/mol** with 4 significant figures => Answers *a*, *b* or *d*.

Number of moles *n* = mass *m* / molar mass *M* = 10.000g / 100.087 $g.mol^{-1}$ => *n* = 0.099913 mol
***n* = 9.991×10^{-2} mol** with 4 significant figures

Number of unit formulas = Number of moles x Avogadro's number
Number of unit formulas = 0.099913 mol x 6.022×10^{23} unit formulas/mole = 6.01677×10^{22} unit formulas
Number of unit formulas = 6.017×10^{22} unit formulas with 4 significant figures => Answers *b*

Only answer b is correct

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19. Balance the following combustion reaction and give the coefficient of Cu

NH_3 *(g)* + CuO *(s)* → N_2 *(g)* + Cu *(s)* + H_2O *(g)*

a. 1
b. 2
c. 3
d. 4
e. 6

Answer: c. 3

NH_3 *(g)* + CuO *(s)* → N_2 *(g)* + Cu *(s)* + H_2O *(g)*

1. Balancing N: **2** NH_3 *(g)* + CuO *(s)* → N_2 *(g)* + Cu *(s)* + H_2O *(g)*
2. Balancing H: 2 NH_3 *(g)* + CuO *(s)* → N_2 *(g)* + Cu *(s)* + **3** H_2O *(g)*
3. Balancing O: 2 NH_3 *(g)* + **3** CuO *(s)* → N_2 *(g)* + Cu *(s)* + 3 H_2O *(g)*
4. Balancing Cu: 2 NH_3 *(g)* + 3 CuO *(s)* → N_2 *(g)* + **3** Cu *(s)* + 3 H_2O *(g)*

5. Checking: 2 N, 6 H, 3 Cu, 3 O 2 N, 6 H, 3 Cu, 3 O
=> It is balanced for all elements => ***3 Cu***

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20. A compound containing 71.65 % Cl, 24.27 % C and 4.07 % H by mass has a molar mass of 98.96 g/mol. Determine its molecular formula.

a. CH_2Cl
b. $C_2H_4Cl_2$
c. $C_4H_6Cl_4$
d. $C_2H_6Cl_2$
e. $C_2H_3Cl_2$

Answer: b. $C_2H_4Cl_2$

The mass of each element in % gives the mass of each in grams, in 100 g of compound.
The number of moles *n* of each element is equal to its mass *m* divided by its molar mass *M* (average atomic mass obtained from the periodic table): $n = m/M$

71.65 % Cl => n[Cl] = 71.65 g / 35.45 $g.mol^{-1}$ = 2.021mol of Cl
24.27 % C => n[C] = 24.27 g / 12.01 $g.mol^{-1}$ = 2.021 mol of C

4.07 % H => n[H] = 4.07 g / 1.008 $g.mol^{-1}$ = 4.038 mol of H

Taking the Cl : C : H ratio, i.e. dividing all number of moles by the smallest (Cl or C since they are equal... let's take Cl):

n[Cl] / n[Cl] = 2.021 / 2.021 = 1
n[C] / n[Cl] = 2.021 / 2.021 = 1
n[H] / n[Cl] = 4.038 / 2.021 = 1.998 ≈ 2
=> Empirical formula : CH_2Cl

Mass of 1 mol of empirical formula = M[CH_2Cl] = 12.01 + (2 x 1.008) + 35.45 = 49.476 g/mol
Molar mass / Mass of 1 mol of empirical formula = molar mass / M[CH_2Cl] = 98.96 g/mol / 49.476 g/mol
Molar mass / Mass of 1 mol of empirical formula = 2.000 = 2
=> The molecular formula contains twice the empirical formula
=> The molecular formula is 2 x [CH_2Cl] = ***$C_2H_4Cl_2$***