Key

Chapter 10
The Mole

Mathematics with Chemical Formulas

Mole Conversions
% Composition
Empirical & Molecular Formulas

mole finding tool

grams $\underset{\div MM}{\overset{\times MM}{\rightleftarrows}}$ moles $\underset{\div 6.0\times10^{23}}{\overset{\times 6.0\times10^{23}}{\rightleftarrows}}$ particles

To find Molar Mass (MM)

Add up each atomic mass by the # of each element

Ex. H_2O

$(2\times1) + (1\times16) = 18\ g/mol$

(1 ↑ Atomic Mass of H; 16 ↑ Atomic Mass of O)

To find % Composition

$$\%\ part = \frac{mass\ part}{mass\ whole} \times 100$$

To find the Empirical Formula

- Formula Finding Tool

% or mass		
MM		
moles		

← a column for each element

- once you have moles, divide all moles by the smallest # of moles to get the ratio.

To Find Molecular Formula

1. Find the Empirical Formula
2. Calculate the mass of Empirical Formula
3. Divide Molar Mass (given) by the Empirical Mass
4. Multiply Emp. Formula by the answer of Step 3.

Molar Mass Worksheet

Calculate the molar masses of the following chemicals:

1) Cl_2 = $2 \times 35.5 = 71$ g/mole

2) KOH = $(1 \times 39) + (1 \times 16) + (1 \times 1) = 56$ g/mole

3) $BeCl_2$ = $(1 \times 9) + (2 \times 35.5) = 80$ g/mole

4) $FeCl_3$ = $(1 \times 55.8) + (3 \times 35.5) = 162.3$ g/mole

5) BF_3 = $(1 \times 10.8) + (3 \times 19) = 67.8$ g/mole

6) CCl_2F_2 = $(1 \times 12) + (2 \times 35.5) + (2 \times 19) = 121$ g/mole

7) $Mg(OH)_2$ = $(1 \times 24.3) + (2 \times 16) + (2 \times 1) = 58.3$ g/mole

8) UF_6 = $(1 \times 238) + (6 \times 19) = 352$ g/mole

9) SO_2 = $(1 \times 32) + (2 \times 16) = 64$ g/mole

10) H_3PO_4 = $(3 \times 1) + (1 \times 31) + (4 \times 16) = 98$ g/mole

11) $(NH_4)_2SO_4$ = $(2 \times 14) + (8 \times 1) + (1 \times 32) + (4 \times 16) = 132$ g/mole

12) CH_3COOH = $(2 \times 12) + (4 \times 1) + (2 \times 16) = 60$ g/mole

13) $Pb(NO_3)_2$ = $(1 \times 207.2) + (2 \times 14) + (6 \times 16) = 331.2$ g/mole

14) $Ga_2(SO_3)_3$ = $(2 \times 69.7) + (3 \times 32) + (9 \times 16) = 379.4$ g/mole

Moles and Molar Mass Worksheet

I. Determine the molar masses of the following substances.

A. $CaCl_2$ $(1\times40)+(2\times35.5)=$ 111 g/mole

B. CO_2 $(1\times12)+(2\times16)=$ 44 g/mole

C. CH_4 $(1\times12)+(4\times1)=$ 16 g/mole

D. Na_2CO_3 $(2\times23)+(1\times12)+(3\times16)=$ 106 g/mole

E. HgS $(1\times200.6)+(1\times32)=$ 232.6 g/mole

F. Al_2S_3 $(2\times27)+(3\times32)=$ 150 g/mole

G. H_2O $(2\times1)+(1\times16)=$ 18 g/mole

H. $C_{12}H_{22}O_{11}$ $(12\times12)+(22\times1)+(11\times16)=$ 342 g/mole

I. H_2S $(2\times1)+(1\times32)=$ 34 g/mole

J. NH_3 $(1\times14)+(3\times1)=$ 17 g/mole

II. Calculate the following problems.

A. The mass of 1.000 mole of $CaCl_2$ 1 mole × 111 g/mole = 111 g $CaCl_2$

B. The grams of 3.0000 moles of CO_2 3 mole × 44 g/mole = 132 g CO_2

C. The number of moles in 32.0 g of CH_4 32 g CH_4 ÷ 16 g/mole = 2 mol CH_4

D. The mass of 40.0 moles of Na_2CO_3 40 mole × 106 g/mole = 4,240 g Na_2CO_3

E. The moles in 168.0 g of HgS 168 g HgS ÷ 232.6 g/mole = .722 mol HgS

F. The moles in 510.0 g of Al_2S_3 510 g Al_2S_3 ÷ 150 g/mole = 3.4 mol Al_2S_3

G. The moles are in 27.0 g of H_2O 27 g H_2O ÷ 18 g/mole = 1.50 mole H_2O

H. The mass in grams of Avogadro's number (1 mole) of $C_{12}H_{22}O_{11}$ 1 mole × 342 g/mole = 342 g $C_{12}H_{22}O_{11}$

I. The mass in grams of 9.03 moles of H_2S 9.03 mol H_2S × 34 g/mole = 307.02 g H_2S

J. The mass in grams ~~in 1.204~~ moles of NH_3 1.204 mol NH_3 × 17 g/mole = 20.468 g NH_3

III. Consider the molecule $CuNH_4Cl_2$ as you answer the following questions.

A. Name the elements present and how many atoms of each are present.

Cu - 1 N - 1 H - 4 Cl - 2

B. What is the molar mass of this molecule?

$(1\times63.5)+(1\times14)+(4\times1)+(2\times35.5) = 152.5$ g/mole

C. How many moles would be in 6.84 g of this substance?

$6.84\text{ g} \div 152.5\text{ g/mole} =$ .0449 mol $CuNH_4Cl_2$

IV. Answer the following questions.

A. You need 0.01 mole of lead(II) chromate. How much should you weigh on the scale?

$PbCrO_4$

$(1\times207.2)+(1\times52)+(4\times16) = 323.2$ g/mole

.01 mole $\times$ 323.2 g/mole = 3.23 g $PbCrO_4$

B. Given 6.40 g ~~of HBr~~. How many moles is this?

$(1\times1)+(1\times79.9) = 80.9$

6.40 g HBr $\div$ 80.9 g/mole = .0791 mole HBr

C. Write the correct formula of calcium acetate.

$Ca(C_2H_3O_2)_2$

D. What is the molar mass of calcium acetate.

$(1\times40)+(4\times12)+(6\times1)+(4\times16) = 158$ g/mole

E. How many moles are contained in 1.58 g of calcium acetate?

1.58 $\div$ 158 g/mole = .01 mol $Ca(C_2H_3O_2)_2$

F. How much does 0.400 moles of calcium acetete weigh?

.400 moles $\times$ 158 g/mole = 63.2 g

G. Write the formula for oxygen gas.

O_2

(1 mole)

H. What is the mass of Avogadro's number of oxygen molecules?

1 mole $\times$ 32 g/mole = 32 g

grams $\underset{\div MM}{\overset{\times MM}{\rightleftarrows}}$ moles $\underset{\div 6.02\times10^{23}}{\overset{\times 6.02\times10^{23}}{\rightleftarrows}}$ particles

worksheet the mole

I. Convert the following to moles

(a) 48×10^{23} baseballs = 7.97 moles of baseballs

$48\times10^{23}\left(\frac{1\text{ mole}}{6.02\times10^{23}}\right) = 7.97$ moles of baseballs

(b) 3×10^{23} carbon atoms = .498 moles of carbon atoms

$3\times10^{23}\left(\frac{1\text{ mole}}{6.02\times10^{23}}\right) = .498$ moles of carbon

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II Calculate the mass of 1 atoms of silver.

$1\text{ atom} \div 6.02\times10^{23} = 1.66\times10^{-24}$ moles of silver $\times 108$ g/mole $= \boxed{1.79\times10^{-22}\text{ g}}$

III Complete the following chart

Substance	Mass (g)	Molar Mass	Moles	# of Particles
C	12	12	1	6.02×10^{23}
N	7	14	.5	3.01×10^{23}
O	128	16	8	4.82×10^{24}
Na	.115	23	.005	3.01×10^{21}
Fe	2	55.8	.0358	2.16×10^{22}
Ag	3	108	.0278	1.67×10^{22}
CO_2	88	44	2	1.204×10^{24}
H_2O	4.5	18	.25	1.505×10^{23}
H_2SO_4	49	98	.5	3.01×10^{23}

atoms

IV Determine the Molar Mass of

A. S_8 $8 \times 32 = 256$ g/mol

B NH_3 $(1 \times 14) + (3 \times 1) = 17$ g/mol

C $H_2SO_4 = (2 \times 1) + (1 \times 32) + (4 \times 16) = 98$ g/mole

V How many grams are in each of the following?

A. 3 moles of O_2 $3 \text{ mol} \times 32 \text{ g/mole} = 96 \text{ g } O_2$

B 10 moles of H_2O $10 \text{ mol} \times 18 \text{ g/mole} = 180 \text{ g } H_2O$

C 2.5 moles of H_2SO_4 $2.5 \text{ mol} \times 98 \text{ g/mol} = 245 \text{ g } H_2SO_4$

D .75 moles of NH_3 $.75 \text{ mol} \times 17 \text{ g/mole} = 12.75 \text{ g } NH_3$

grams $\xleftarrow[\div MM]{\times MM}$ moles $\xrightarrow[\div 6.02\times10^{23}]{\times 6.02\times10^{23}}$ particles

SUBSTANCE	GRAMS USED	MOLAR MASS	MOLES	# OF PARTICLES
C	48	12	4	2.408×10^{24}
P	124	31	4	2.408×10^{24}
Ag	27	108	.25	1.505×10^{23}
Cu	31.6	63.5	.498	3 x 1023
NO_2	138	46	3	1.806×10^{24}
H_3PO_4	9.77	98	.09967	.6 x 1023
SO_3	200	80	2.5	1.505×10^{24}
HNO_3	47.25	63	.75	4.515×10^{23}

PRACTICE WITH MOLES

1. Calculate the number of moles in 65.0 grams of gold.

$65\,g \div 197\,g/mole = .330\ mol\ Au$

2. Calculate the number of grams in 4.00 moles of mercury.

$4\ mol\ Hg \times 200.6\,g/mol = 802.4\,g\ Hg$

3. Calculate the number of atoms you have if you have 0.50 moles of barium

$.5\ mol\ Ba \times 6.02\times10^{23}\ \frac{atom}{mol} = 3.01\times10^{23}\ atoms$

4. Calculate the number of atoms in 24.56 grams of sulfur.

$24.56\,g\,S\left(\frac{1\ mol\ S}{32\,g}\right) = .765\ mol\ S \times 6.02\times10^{23}\ \frac{atoms}{mol} = 4.62\times10^{25}\ atoms$

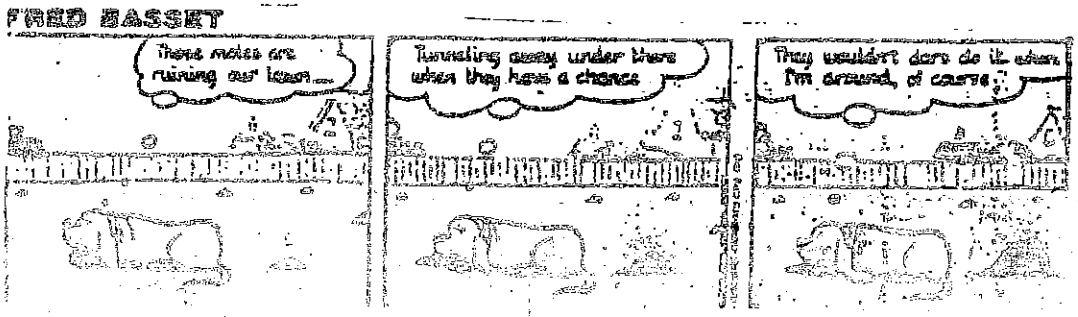
5. If you have 3.01×10^{23} atoms of zinc, how many moles of zinc do you have?

$3.01\times10^{23}\ atoms\ Zn \div 6.02\times10^{23} = .500\ mol\ Zn$

6. If you have 1.81×10^{24} atoms of sodium, what would it weigh?

$1.81\times10^{24}\ atoms \div 6.02\times10^{23} = 3.01\ mol\ Na \times 23\,g/mol = 69.2\,g\ Na$

Answers: 1) 0.330 mol 2) 804 g 3) 3.0×10^{23} atoms 4) 4.61×10^{23} atom
5) 0.500 mol 6) 69.0 grams



MOLES AND MASS

Name _____

Determine the number of moles in each of the quantities below.

1. 25 g of NaCl (23, 35.5)	$25_g \div 58.5\ g/mol = .427\ mol\ NaCl$
2. 125 g of H_2SO_4 ((2×1)+(1×32)+(4×16))	$125_g\ H_2SO_4 \div 98\ g/mol =$ 1.28 mol H_2SO_4
3. 100. g of $KMnO_4$ (39.1 + 54.9 + (4×16) = 158 g/mol)	$100_g \div 158\ g/mol =$ .633 mol $KMnO_4$
4. 74 g of KCl (39.1, 35.5, 74.6)	$74_g \div 74.6\ g/mol =$ .992 mol KCl
5. 35 g of $CuSO_4 \cdot 5H_2O$ (63.5, 32, (4×16), (10×1), (5×16) = 249.5 g)	$35_g \div 249.5\ g/mol =$ .140 mol $CuSO_4 \cdot 5H_2O$

Determine the number of grams in each of the quantities below.

1. 2.5 moles of NaCl	2.5 mol × 58.5 g/mol = 146.25 g
2. 0.50 moles of H_2SO_4	.5 mol H_2SO_4 × 98 g/mol = 49 g
3. 1.70 moles of $KMnO_4$	1.70 mol × 158 g/mol = 268.6 g
4. 0.25 moles of KCl	.25 mol × 74.6 g/mol = 18.65 g
5. 3.2 moles of $CuSO_4 \cdot 5H_2O$	3.2 mol × 249.5 g/mol = 798.4 g

PERCENTAGE COMPOSITION

Name _____

Determine the percentage composition of each of the compounds below.

1. $KMnO_4$ (39.1 + 54.9 + (4×16) = 158)

K = 24.7%
Mn = 34.7%
O = 40.5%

$\%K = \frac{\text{mass K}}{\text{mass } KMnO_4} \times 100 = \frac{39.1}{158} \times 100 = 24.7\%\ K$

$\%Mn = \frac{\text{mass Mn}}{\text{mass } KMnO_4} \times 100 = \frac{54.9g}{158} \times 100 = 34.7\%\ Mn$

$\%O = \frac{\text{mass O}}{\text{mass } KMnO_4} \times 100 = \frac{64}{158} \times 100 = 40.5\%$

2. HCl (1 + 35.5 = 36.5)

H = 2.74%
Cl = 97.

$\%H = \frac{\text{mass H}}{\text{mass HCl}} \times 100 = \frac{1g}{36.5g} \times 100 = 2.74\%\ H$

$\%Cl = \frac{\text{mass Cl}}{\text{mass HCl}} \times 100 = \frac{35.5g}{36.5g} \times 100 = 97.26\%\ Cl$

3. $Mg(NO_3)_2$ (24.3 (Mg) + (6×16) = 148.3)

Mg = 16.39%
N = ~~9.44~~ 18.88%
O = 64.73%

$\%Mg = \frac{\text{mass Mg}}{\text{mass } Mg(NO_3)_2} \times 100 = \frac{24.3}{148.3} \times 100 = 16.39\%\ Mg$

$\%N = \frac{\text{mass N}}{\text{mass } Mg(NO_3)_2} \times 100 = \frac{28}{148.3} \times 100 = 18.88\%\ N$

$\%O = \frac{\text{mass O}}{\text{mass whole}} \times 100 = \frac{96}{148.3} \times 100 = 64.73\%\ O$

4. $(NH_4)_3PO_4$ ((3×14) + (12×1) + (1×31) + (4×16) = 149)

N = 28.19%N
H = 8.05%H
P = 20.81%P
O = 42.95%O

$\%N = \frac{42g}{149g} \times 100 = 28.19\%N$

$\%H = \frac{12g}{149g} \times 100 = 8.05\%H$

$\%P = \frac{31}{149} \times 100 = 20.81\%P$

$\%O = \frac{64g}{149g} \times 100 = 42.95\%O$

5. $Al_2(SO_4)_3$ ((2×27) + (3×32) + (12×16) = 342g)

Al = 15.79%
S = 28.07%
O = 56.14%

$\%Al = \frac{54g}{342g} \times 100 = 15.79\%\ Al$

$\%S = \frac{96g}{342g} \times 100 = 28.07\%\ S$

$\%O = \frac{192g}{342g} \times 100 = 56.14\%O$

Solve the following problems. $\%O = \frac{(3\times16)}{122.6} \times 100 = 39.15\%O$

6. How many grams of oxygen can be produced from the decomposition of 100. g of $KClO_3$? 39.15g O $.3915 \times 100 = 39.15g\ O$

7. How much iron can be recovered from 25.0 g of Fe_2O_3? $\%Fe = \frac{(2\times55.8)}{159.6} = 69.9\% = 17.48g\ Fe$

8. How much silver can be produced from 125 g of Ag_2S? 108.9g Ag $.870 \times 125 =$

$\%Ag = \frac{216g}{248} \times 100 = 87.10\%\ Ag$

WORKSHEET: PERCENTAGE COMPOSITION

FIND THE PERCENTAGE COMPOSITION OF EACH COMPOUND LISTED BELOW.

1. FeO

$\%Fe = \frac{\text{mass Fe}}{\text{mass FeO}} \times 100 = \frac{55.8}{(55.8+16)} = \frac{55.8}{71.8} \times 100 = 77.7\%\ Fe$

$\%O = \frac{\text{mass O}}{\text{mass FeO}} \times 100 = \frac{16g}{71.8g} \times 100 = 22.3\%O$

2. HgO

200.6 16 → 216.6

$\%Hg = \frac{\text{mass Hg}}{\text{mass HgO}} \times 100 = \frac{200.6}{216.6} \times 100 = 92.6\%\ Hg$

$\%O = \frac{\text{mass O}}{\text{mass HgO}} \times 100 = \frac{16}{216.6} \times 100 = 7.4\%\ O$

3. NH_3

14 (3×1) → 17

$\%N = \frac{\text{mass N}}{\text{mass } NH_3} \times 100 = \frac{14}{17} \times 100 = 82.4\%N$

$\%H = \frac{\text{mass H}}{\text{mass } NH_3} \times 100 = \frac{3}{17} \times 100 = 17.6\%H$

4. CH_4

12 4×1 → 16

$\%C = \frac{\text{mass C}}{\text{mass } CH_4} \times 100 = \frac{12}{16} \times 100 = 75\%\ C$

$\%H = \frac{\text{mass H}}{\text{mass } CH_4} \times 100 = \frac{4}{16} \times 100 = 25\%H$

5. A compound consisting of aluminum and chlorine weighs 17.82 grams. The aluminum in the compound weighs 3.60 grams. What is the mass of chlorine in the compound? What is the percentage composition of the compound?

Total: 17.82g
Al: 3.60g
Cl: 14.22g
} Add up to 17.82

mass Cl = total mass − mass Al = 17.82g − 3.60g = 14.22g Cl

$\%Al = \frac{\text{mass Al}}{\text{mass whole}} = \frac{3.60}{17.82} \times 100 = 20.2\%Al$

$\%Cl = \frac{\text{mass Cl}}{\text{mass whole}} = \frac{14.22}{17.82} \times 100 = 79.8\%Cl$

6. A compound consisting of carbon, hydrogen, and oxygen weighs 40.85 grams. Analysis shows that the compound contains 10.90 grams of carbon and 0.90 g of hydrogen. What is the percentage composition of the compound?

Total: 40.85g
C: 10.9g
H: .9g
O: 29.05g
} Add up to 40.85

$\%C = \frac{10.9g}{40.85g} \times 100 = 26.7\%C$

$\%O = \frac{29.05g}{40.85g} \times 100 = 71.1\%O$

$\%H = \frac{.9}{40.85} \times 100 = 2.2\%H$

EMPIRICAL FORMULA WORKSHEET: - Simlest whole # ratio of elements in a compound

1. A compound contains 72 grams of carbon and 16 grams of hydrogen. Determine the empirical formula.

	C	H
mass	72	16
MM	12	1
moles	6	16

ratio C:H
6:16
3:8

Emp. Formula
C_3H_8

2. What is the empirical formula for a compound if a 22 gram sample of it consists of 14 grams nitrogen and 8.0 grams oxygen?

	N	O
mass	14	8
MM	14	16
moles	1	.5

.5

N:O
2:1

Emp Form
N_2O

3. A 100 gram sample of an oxide of chromium is found to contain 68.4 grams of chromium and 31.6 grams of oxygen. What is the empirical formula of this compound?

	Cr	O
mass	68.4	31.6
MM	52	16
moles	1.32	1.98

1.32

Cr:O
(1:1.5)×2
2:3

Emp Form
Cr_2O_3

4. A compound contains 52.0% zinc, 9.6% carbon, and 38.4% oxygen. Determine the empirical formula for the compound.

	Zn	C	O
%	52	9.6	38.4
MM	65.4	12	16
moles	.795	.8	2.4

.795

Zn:C:O
1:1:3

Emp Form
$ZnCO_3$

5. 50.0 grams of sulfur are mixed with 100.0 grams of iron and the mixture is heated. When the reaction is completed, 12.7 grams of iron remain. What is the formula of the compound formed?

100_g Fe to start − 12.7 g Fe remain = 87.3_g Fe used

	Fe	S
mass	87.3_g	50_g
MM	55.8	32
moles	1.56	1.56

1.56

Fe:S
1:1

Emp Formula
FeS

EET: EMPIRICAL AND MOLECULAR FORMULAS

Upon analysis, 102 grams of aluminum oxide are found to contain 54 grams of aluminum. Calculate the simplest formula of the aluminum oxide.

	Al	O
mass	54	48
MM	27	16
mole	2	3

Al:O
2:3

Al_2O_3

2. The analysis of a compound yields the following composition in grams: hydrogen, 3.06 grams; phosphorus, 31.63 grams; oxygen, 65.30 grams. What is the empirical formula for this compound?

H:P:O
3:1:4

H_3PO_4

	H	P	O
mass	3.06	31.63	65.30
MM	1	31	16
moles	3.06	1.02	4.08

3. A substance was found to have the following composition: potassium, 26.57%; chromium, 35.36%; oxygen, 38.07%. Find the empirical formula.

	K	Cr	O
%	26.57	35.36	38.07
MM	39.1	52	16
mole	.680	.68	2.38

K:Cr:O
(1:1:3.5)×2
2:2:7

$K_2Cr_2O_7$

4. A sample of an oxide of iron contains 27.59% oxygen and 72.4% iron. Calculate the empirical formula.

	Fe	O
	72.4	27.59
	55.8	16
	1.3	1.72

Fe:O
(1:1.33)×3
3:4

Fe_3O_4

5. 9.21 grams of calcium are heated in an excess of nitrogen. The final product weighs 11.38 grams. Calculate its empirical formula.

g N = 11.38 − 9.21 = 2.17 g

	Ca	N
mass	9.21	2.17
MM	40	14
mole	.230	.155

Ca:N
(1.5:1)×2
3:2

Ca_3N_2

6. A compound yielded this data on analysis: carbon, 92.31%; hydrogen, 7.69%; molar mass, 78. Determine its molecular formula.

	C	H	7.69
mass	92.31	92.31	
MM	12	1	
mole	7.69	7.69	

C:H
1:1

Emp Form = CH

Mass of EF = 12+1 = 13

Molar Mass / Emp. Mass = 78/13 = 6

Molecular Form = C_6H_6

7. A hydrocarbon contains 80 grams of carbon and 20 grams of hydrogen. Its molar mass is 30. What is its molecular or true formula?

	C	H
mass	80	20
MM	12	1
mole	6.67	20

C:H
1:3

E.F. = CH_3

Mass of EF = (12×1)+(3×1) = 15

Molar Mass / Emp. Mass = 30/15 = 2

Molecular Form = C_2H_6

8. The percentage composition of a substance is as follows: carbon, 40.0%; hydrogen, 6.6%; oxygen, 53.4%. Its molar mass is 180. What is its molecular formula?

	C	H	O
%	40	6.6	53.4
MM	12	1	16
mole	3.33	6.6	3.33

C:H:O
1:2:1

EF: CH_2O

Mass of EF = 12+(2×1)+16 = 30

Molar Mass / Emp Mass = 180/30 = 6

Molec Form: $C_6H_{12}O_6$

9. What is the molecular formula of a substance which contains 30.45% nitrogen and 69.55% oxygen. Its molar mass is 46.

	N	O
mass	30.45	69.55
MM	14	16
moles	2.175	4.35

N:O
1:2

EF = NO_2

Mass of EF = 14+(2×16) = 46

Molar Mass / Emp Mass = 46/46 = 1

Molecular: NO_2