

SI Chemistry - Full Discipline Demo

The Mole: Conversions, Mass Determination, and Hydrates

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Arrange each chemical in order of mass, from smallest mass to largest mass.

≡ 1.0 moles PbCl_2

1 **Correct answer:** 5.0 moles H_2

≡ 1.5 moles Na

2 **Correct answer:** 1.5 moles Na

≡ 2.0 moles N_2

3 **Correct answer:** 2.0 moles N_2

≡ 3.0 moles $\text{CH}_3\text{CH}_2\text{OH}$

4 **Correct answer:** 3.0 moles $\text{CH}_3\text{CH}_2\text{OH}$

≡ 5.0 moles H_2

5 **Correct answer:** 1.0 moles PbCl_2

Typesetting math: 100%

Match each prefix to the appropriate hydrate it would be used to name.

⚡ deca	$\text{BaCl}_2 \cdot 6\text{H}_2\text{O}$	1
⚡ di	$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	2
⚡ hepta	$\text{BeCl}_2 \cdot 2\text{H}_2\text{O}$	3
⚡ hexa	$\text{IrBr}_3 \cdot 10\text{H}_2\text{O}$	4
⚡ penta	$\text{Co}_3\text{PO}_4 \cdot 7\text{H}_2\text{O}$	5

Correct answers:

1 hexa 2 penta 3 di 4 deca 5 hepta

Typesetting math: 100%

What is the atomic mass of helium?

⋮
1 amu

⋮
3 amu

⋮
4 amu

⋮
8 amu

2

Helium

He

He

Atomic mass:

Correct answers:

1 4 amu

Exploration

The molar mass of carbon dioxide (CO_2) is ____.

- ☒ 44.0 g/mol

☐ 47.0 g/mol

☐ 43.0 g/mol

☐ 42.5 g/mol
- ✓

Typesetting math: 100%

In 85.2 g of FeCl_2 there are _____ moles of FeCl_2 .

- ☐ 1.52
- ☐ 2.00
- ☒ 0.672
- ☐ 0.933

✓

In 85.2 g of FeCl_2 there are _____ moles of chlorine.

- ☒ 1.34
- ☐ 0.672
- ☐ 2.00
- ☐ 2.69

✓

The first step when converting between mass of a compound and moles of a compound is to determine the molar mass of the compound.

- ☒ True
- ☐ False

✓

Water is released from a hydrate by ____.

- ☒ heating the hydrate
- ☐ cooling the hydrate
- ☐ adding water to the hydrate
- ☐ None of the above

✓

Exercise 1

Describe the relationship between moles and atoms.

Typesetting math: 100%

The unit of measure referred to as a mole is used for the counting of atoms. A mole (n) is a unit of measure, describing the amount of a chemical substance that contains as many atoms, molecules, or formula units as there are in exactly 12 grams of pure carbon-12 (^{12}C). This amount of atoms (6.022×10^{23}) is referred to as Avogadro's number. Thus, a 12.01 g sample of the average, naturally occurring carbon contains 6.022×10^{23} atoms.

A sample of 2 tsp of sugar ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) weighs 9.00 g.

a. Record each step needed to calculate the moles and atoms of all elements present in the sample.

b. Then, calculate the moles and atoms of each element in the sample of sugar. Show all work to answer this question by uploading an image of your calculations into Photo 1.

The first step to calculate the number of moles and atoms of elements present in a sample is to calculate the molar mass of the compound by using the Periodic Table to determine the atomic mass of each element and multiplying by 1 g/mol. Then the sum of the molar masses is added (included multiplying any elements by the number of atoms present in the compound) to determine the molar mass of the compound. The molar mass is then used to convert the grams of the sample to moles by dividing the grams of the sample by the molar mass of the compound. Once the moles of the compound are calculated, then the moles of each element can be calculated by individually multiplying the moles of the compound by the number of atoms of the element present in the compound. The atoms can then be calculated by multiplying the moles of each element by Avogadro's number (6.022×10^{23}).

Which item in Data Table 1 contains the largest quantity of moles?

The glass stirring rod contains the largest quantity of moles.

If you were given a sample of a cotton ball and a glass stirring rod with identical mass (ex: 5.0 g), which sample would contain more oxygen atoms?

Typesetting math: 100%

If both samples had a mass of 5.0g the glass stirring rod (SiO_2) would contain 1.01×10^{23} oxygen atoms and the cotton ball ($\text{C}_6\text{H}_{10}\text{O}_5$) would contain 9.28×10^{22} atoms of oxygen. That means that the glass stir rod contains more oxygen atoms.

Data Table 1: Moles and Atoms in Common Items
(SAMPLE ANSWER BELOW)

Item	Formula	Molar Mass (g/mol)	Mass of Sample (g)	Moles of Sample (mol)	Moles of Each Element (mol)	Atoms of Each Element
Aluminum Cup	Al	26.982	2.35	0.0871	Al: 0.0871	Al: 5.25×10^{22}
Glass Stirring Rod	SiO_2	60.084	6.89	0.115	Si: 0.115	Si: 6.93×10^{22}
					O: 0.230	O: 1.39×10^{23}
Cotton Ball	$\text{C}_6\text{H}_{10}\text{O}_5$	162.081	0.59	0.0036	C: 0.022	C: 1.3×10^{22}
					H: 0.036	H: 2.2×10^{22}
					O: 0.018	O: 1.1×10^{22}

Photo 1: Question 2 Calculations
(SAMPLE ANSWER BELOW)

Sample of 2 tsp of $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ weighing 9.00 g:

Atomic mass of carbon (C): 12.011

Atomic mass of hydrogen (H): 1.008

Atomic mass of oxygen (O): 15.999

Molar mass of carbon (C): $12.011 \times 1 \text{ g/mol}$

Molar mass of hydrogen (H): $1.008 \times 1 \text{ g/mol}$

Molar mass of oxygen (O): $15.999 \times 1 \text{ g/mol}$

Molar mass of $\text{C}_{12}\text{H}_{22}\text{O}_{11} = (12 \times 12.011 \text{ g/mol}) + (22 \times 1.008 \text{ g/mol}) + (11 \times 15.999 \text{ g/mol}) = 342.297 \text{ g/mol}$

$$9.00 \text{ g } \text{C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{1 \text{ mol } \text{C}_{12}\text{H}_{22}\text{O}_{11}}{342.297 \text{ g } \text{C}_{12}\text{H}_{22}\text{O}_{11}} = 0.0263 \text{ mol of } \text{C}_{12}\text{H}_{22}\text{O}_{11}$$

$$0.0263 \text{ mol of } \text{C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{12 \text{ mol C}}{1 \text{ mol } \text{C}_{12}\text{H}_{22}\text{O}_{11}} = 0.316 \text{ mol of C}$$

Typesetting math: 100%

$$0.0263 \text{ mol of } \text{C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{22 \text{ mol H}}{1 \text{ mol } \text{C}_{12}\text{H}_{22}\text{O}_{11}} = 0.579 \text{ mol of H}$$

$$0.0263 \text{ mol of } C_{12}H_{22}O_{11} \times \frac{1 \text{ mol } C_{12}H_{22}O_{11}}{1 \text{ mol } C_{12}H_{22}O_{11}} = 0.0263 \text{ mol of } C_{12}H_{22}O_{11}$$

$$0.0263 \text{ mol of } C_{12}H_{22}O_{11} \times \frac{11 \text{ mol O}}{1 \text{ mol } C_{12}H_{22}O_{11}} = 0.289 \text{ mol of O}$$

$$0.316 \text{ mol C} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol C}} = 1.90 \times 10^{23} \text{ atoms of C}$$

$$0.579 \text{ mol H} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol H}} = 3.49 \times 10^{23} \text{ atoms of H}$$

$$0.289 \text{ mol O} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol O}} = 1.74 \times 10^{23} \text{ atoms of O}$$

Exercise 2

Calculate the moles of anhydrous (dry) $KAl(SO_4)_2$ that were present in the sample. Show all work to answer this question by uploading an image of your calculations into Photo 2.

$$0.90 \text{ g } KAl(SO_4)_2 \times 1 \text{ mol } KAl(SO_4)_2 / 258.2 \text{ g} = 0.0035 \text{ mols } KAl(SO_4)_2$$

Typesetting math: 100%

Calculate the ratio of moles of H_2O to moles of anhydrous $\text{KAl}(\text{SO}_4)_2$. Show all work to answer this question by uploading an image of your calculations into Photo 3. Note: Report the ratio to the closest whole number.

Ratio = $0.061 \text{ mols H}_2\text{O} / 0.0035 \text{ mols KAl}(\text{SO}_4)_2$
Ratio = 17

Write the empirical formula for the hydrated $\text{KAl}(\text{SO}_4)_2$, based on your experimental results and answer to Question 2. Show all work to answer this question by uploading an image of your calculations into Photo 4.

Hint: if the ratio of moles of H_2O to moles of anhydrous $\text{KAl}(\text{SO}_4)_2$ was 4, then the empirical formula would be: $\text{KAl}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$.

The empirical formula, using the calculated data is:
 $\text{KAl}(\text{SO}_4)_2 \cdot 17\text{H}_2\text{O}$

Describe any visual differences between the hydrated sample and the dried, anhydrous form.

The hydrated sample appears to be small, circular, damp particles. They move well in the aluminum cup and have a shiny, metallic appearance. The dried, anhydrous form looks very dried out, it is clumped together and is unable to move in as small particles. It looks like molten lava.

Typesetting math: 100%

How would the following errors affect the empirical formula for the compound?

a. The student ran out of time and did not do the second heating. Explain how this error will affect the calculation for the number of moles of water in the hydrate? Will the final answer be artificially high or low? How do you know?

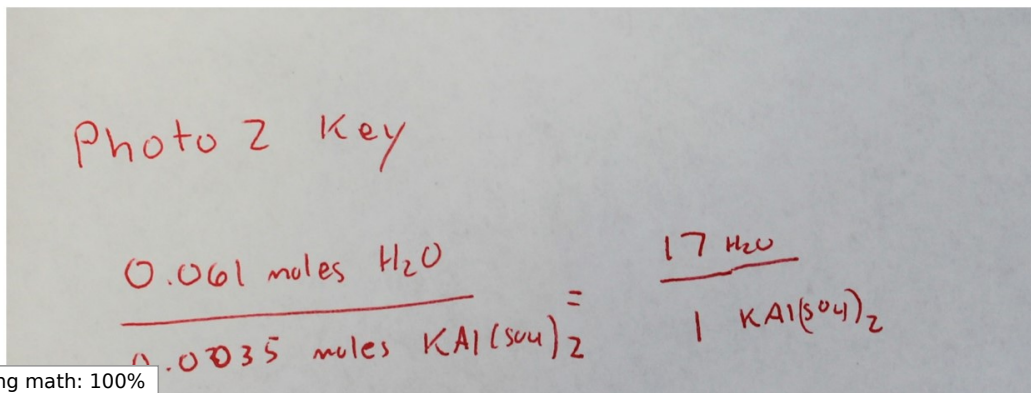
b. The student recorded the mass of the cup + sample incorrectly and started with 2.2 g of hydrated compound but used 2.0 g in the calculations. Explain how this error will affect the calculation for the number of moles of water in the hydrate? Will the final answer be artificially high or low? How do you know?

- a. Not all of the water would have been released, resulting in a hydrate calculation that has too few moles of water.
b. The sample would have "released" more water, resulting in a hydrate calculation that included more moles of water than were actually present.

Data Table 2: Alum Data
(SAMPLE ANSWER BELOW)

Object	Mass (g)
Aluminum Cup (Empty)	2.50
Aluminum Cup + 2.0 grams of Alum	4.50
Aluminum Cup + Alum After 1st Heating	3.40
Aluminum Cup + Alum After 2 nd Heating	3.40
Mass of Released H ₂ O	1.10
Molar mass of H ₂ O	18.015
Moles of Released H ₂ O	0.0611

Photo 2: Question 1 Calculations
(SAMPLE ANSWER BELOW)



Typesetting math: 100%

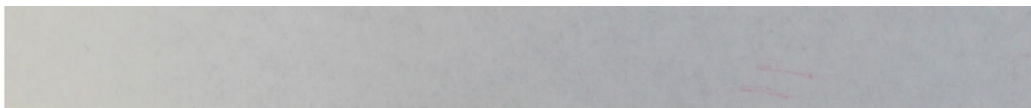
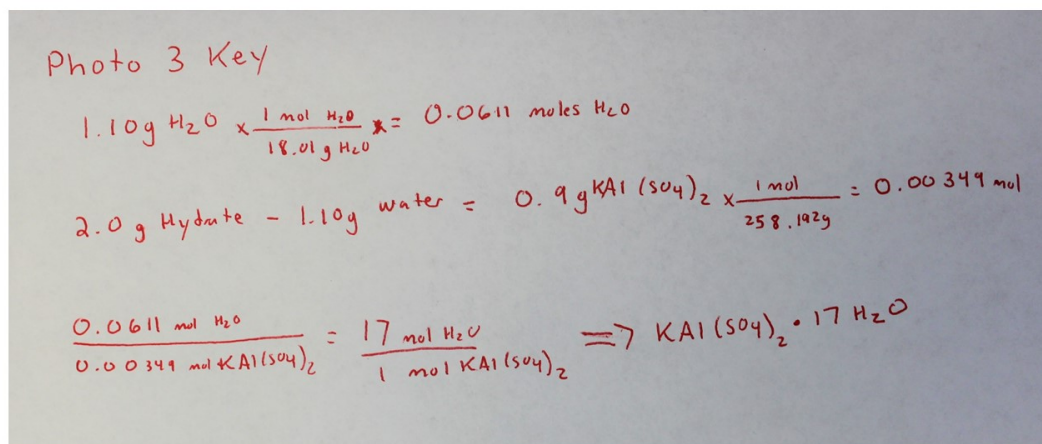


Photo 3: Question 2 Calculations
(SAMPLE ANSWER BELOW)



Typesetting math: 100%

Photo 4: Question 3 Calculations
(SAMPLE ANSWER BELOW)



Typesetting math: 100%

Competency Review

There are ____ atoms in 12 grams of pure carbon (^{12}C).

- ☐ 12.022×10^{23}
- ☒ 6.022×10^{23} ✓
- ☐ 4.023×10^{23}
- ☐ 1.00×10^{23}

One mole of a compound has the mass that is equal to the molecular mass.

- ☒ True ✓
- ☐ False

Typesetting math: 100%

The element oxygen has a molar mass of 15.999 grams, thus one mole of oxygen is equal to ____ g/mol.

- ☐ 31.998
- ☐ 15.999×10^{23}
- ☒ 15.999
- ☐ 31.998×10^{23}

✓

A hydrate is a compound in which water molecules are a part of the crystalline structure.

- ☒ True
- ☐ False

✓

When copper sulfate heptahydrate is heated, how many moles of water are available to be released?

- ☐ 1
- ☐ 4
- ☒ 7
- ☐ 9

✓

The second step in converting between the mass of a compound and moles of a compound is to use the molar mass to convert grams to moles.

- ☒ True
- ☐ False

✓

Calculate the moles of anhydrous CuSO_4 present in a sample with 0.5 g CuSO_4 at a molar mass of 159.61 g/mol.

- ☒ 0.00313
- ☐ 0.00853
- ☐ 0.00710
- ☐ 0.00626

✓

Typesetting math: 100%

Based on the correct answer to question 7, calculate the ratio of moles of H_2O to moles of anhydrous CuSO_4 if there were 0.085 mols of released H_2O .

- ☐ 12
- ☐ 10
- ☒ 27
- ☐ 5

✓

After heating a sample of hydrated CuSO_4 , the mass of released H_2O was found to be 2.0 g. How many moles of H_2O were released if the molar mass of H_2O is 18.016 g/mol?

- ☐ 0.004
- ☒ 0.111
- ☐ 9.031
- ☐ 0.222

✓

Based on the correct answer to question 8, what is the empirical formula for hydrated CuSO_4 ?

- ☒ $\text{CuSO}_4 \cdot 27\text{H}_2\text{O}$
- ☐ $\text{CuSO}_4 \cdot 12\text{H}_2\text{O}$
- ☐ $\text{CuSO}_4 \cdot 10\text{H}_2\text{O}$
- ☐ $\text{CuSO}_4 \cdot \text{H}_2\text{O}$

✓

Extension Questions

Cu (II) sulfate exists as a hydrate. It has many practical uses including use as a fungicide and pesticide. When mixed with chromium and arsenic it forms the wood preservative called CCA. CCA was used in pressure treated wood to protect wood from rotting due to insects and microbial agents. Because CCA treated wood contains toxic heavy metals, its use has been discontinued for home use and children's play sets.

A chemist is given a sample of the CuSO_4 hydrate and asked to determine the empirical formula of it. The original sample weighed 42.75 g. After heating to remove the waters of hydration, the sample weighed 27.38 g. Determine the formula for this hydrate. Show your work.

(SAMPLE ANSWER BELOW)

Typesetting math: 100%

Mass of water removed = $42.75\text{ g} - 27.38\text{ g} = 15.37\text{ g}$ Moles of water removed = $15.37\text{ g} \times 1\text{ mol}/18.0\text{ g} = 0.854\text{ mols}$ Mass of anhydrous copper sulfate = 27.38 g Moles of anhydrous copper sulfate = $27.38\text{ g} \times 1\text{ mol}/159.55\text{ g} = 0.172\text{ mols}$ Moles H_2O /mols $\text{CuSO}_4 = 0.854/0.172 = 4.96 = 5$ (rounded to whole number) Formula = $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

Typesetting math: 100%