Website: contoureducation.com.au | **Phone:** 1800 888 300
Email: hello@contoureducation.com.au

VCE Chemistry ½
Moles & Molar Mass [2.1]
Workbook

Outline:

Key Formulae:

$\boldsymbol{n = \frac{N}{N_A}}$	$\boldsymbol{n = \frac{m}{M}}$	

Learning Objectives:

☐ CH12 [2.1.1] – Apply Avogadro's number to mole & particle calculations ($n = N/N_a$)

☐ CH12 [2.1.2] – Apply molar mass to mole calculations using $n = \frac{m}{M}$

☐ CH12 [2.1.3] – Apply unit conversions to calculation questions

Section A: Moles

Sub-Section: Introduction to Moles

Context

- **Atomic Models:** Different models of atoms and types of bonding have been explored.
- **Small Scale:** Chemistry deals with very small atoms.
- **Counting Atoms:** Sometimes it is necessary to determine the number of atoms.

Exploration: Introduction to Moles

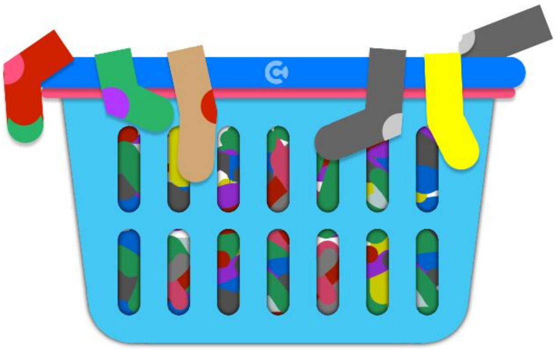
- Consider $12.00\ g$ of carbon (C):

- **Atoms of carbon:** ______________________________

- **Issue:** there are large number of particles, cannot continuously use such large numbers.

What is the solution?

- **Consider a basket of 36 socks:**



- **Different Method of Counting:**

<u>In Pairs</u>	<u>In Dozens</u>

- **Solution**: Chemists 'group up' particles with new unit ______________.

NOTE: The symbol to denote moles is 'n' and not 'm'

ALSO NOTE: The 'unit' for moles is 'mol' (without the 'e').

<u>History</u>: Amedeo Avogadro

Amedeo Avogadro, $1776 - 1856$

- Amedeo Avogadro came up with Avogadro's Number.

Let's look at simple example , hydrogen first!

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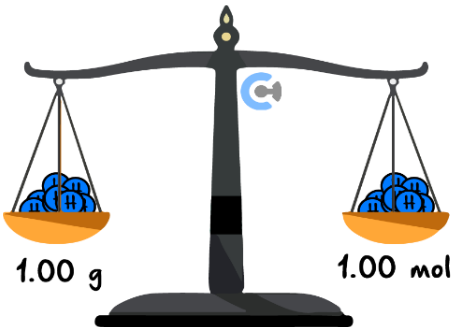
Exploration: Avogadro's Definition of a Mole

- Consider Hydrogen:

$$H$$

- **Definition:**



$$1.00\ g = 1.00\ mol\ of\ hydrogen$$

- Number of atoms in $1.00\ g$ of Hydrogen: ______________________________

- **Constant Name:** ______________________________.

Avogadro's Number

- **Definition:**
  - A **constant/number** which relates the number of **particles** to the number of moles.
  - It can be found on **page 4 of the databook.**

Denoted By	SI Unit	Formulae
N_a	mol^{-1}	$N_a = 6.02 \times 10^{23}\ mol^{-1}$

NOTE: Just like how 1 dozen of eggs = 12 eggs, 1 mole of a substances = 6.02×10^{23} atoms.

Exploration: Mole Calculations

- If **one mole** is $\mathbf{6.02 \times 10^{23}}$ **atoms**, how many atoms are present in **two moles** of carbon?

- **Formula:**

- **Rearranged Formula:**

$$n = \_\_\_\_\_\_$$

Number of Particles

- **Equation:**

$$N = N_A \times n$$

Term	What it represents
N	number of particles (no unit).
N_A	vogadro's Number ($6.02 \times 10^{23}\ mol^{-1}$).
n	number of moles (mol).

NOTE: This formula is not in the Data Book

Misconception

"The unit 'moles' can only be used to count the number of atoms present"

TRUTH: Moles can be used to calculate the amount of anything present.

- **Example** 6.02×10^{23} stars, same as one mole of stars!

Let's have a look at a question together!

Question 1 Walkthrough.

a. Given that there are 2.5 dozen eggs, determine how many eggs are present

b. Given that there are 3.721 mol of hydrogen (H_2), determine how many molecules of hydrogen are present.

TIP: While moles might seem intimidating at first, just remember that it is simply just another unit of measurement to measure how much of something we have!

Active Recall: Complete the table below

	N	N_A	n
What it represents			

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Let's have a look at this in a different form!

Question 2 Walkthrough.

a. Given that there are 40 eggs, determine how many dozens of eggs are present.

b. Given that there are 1.05×10^{25} atoms of sodium, determine how many moles of sodium are present.

TIP: Make sure you use brackets in your calculator when dividing by Avogadro's constant

Recall!

Active Recall: What's the formula to calculate the number of moles from the number of particles?

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Your Turn!

Question 3

a. Calculate the number of atoms of in 5.2 mol of sulphur (S).

b. Calculate the number of atoms in 0.5 mol of nitrogen (N).

Question 4

a. Calculate the number of moles if there are 2.1×10^{24} atoms of neon (Ne).

b. Calculate the number of moles if there are 10 atoms of helium (He).

TIP: Use logic to check if the answer you calculated makes sense!

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Question 5 Additional.

If there are 2 mol of H_2 molecules, state the amount of hydrogen atoms present, in mol?

Space for Personal Notes

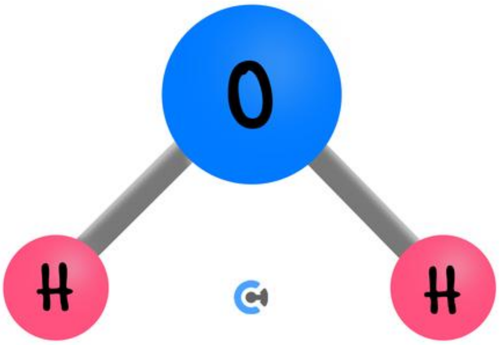
Sub-Section: Moles of Molecules & Atoms

Discussion: If there are 12 moles of water, how many moles of hydrogen atoms and oxygen atoms are there ?

Let's take a look at this idea!

Exploration: Moles of Molecules & Atoms

- Consider water (H_2O):



- For every **one molecule** of water:

Atoms of Oxygen (O)	Atoms of Hydrogen (H)

- For **seven molecules** of water:

Atoms of Oxygen (O)	Atoms of Hydrogen (H)

- For every **five dozens** of molecules water:

Atoms of Oxygen (O)	Atoms of Hydrogen (H)

- For every **five moles** of molecules water:

Atoms of Oxygen (O)	Atoms of Hydrogen (H)

Definition

Moles of Molecules & Atoms

- **Each** water molecule has ________ oxygen atom and ____________ hydrogen atoms
  - When determing moles of atoms from a molecule: must consider **ratios**

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Let's look at some questions together!

Question 6 Walkthrough.

a. Given that there are 8.02×10^{23} molecules of oxalate ions ($C_2O_4{}^{2-}$), determine how many moles of oxalate are present.

b. Hence, how many moles of **atoms** are present in total?

Your Turn!

Question 7

a. Calculate the number of oxygen molecules (O_2) in 3.5 mol of oxygen gas (O_2)

b. Calculate the number of oxygen **atoms** present.

Question 8

Swastik is investigating ammonia (NH_3).

a. If there are 3.10 mol of ammonia (NH_3), find the amount (in mol) of:

i. Nitrogen atoms present.

____

ii. Hydrogen atoms present.

____

b. If 6.00 mol of hydrogen atoms are found from ammonia (NH_3) molecules, find the amount, in mol, of ammonia molecules which are present.

____

____

Question 9 Additional.

Which of the following does **not** contain one mole of hydrogen atoms?

A. 1.0 mol of OH^- (aq) ions.

B. 3.01×10^{23} water molecules.

C. 0.25 mol of ammonium ions (NH_4^+ (aq)).

D. 1.0 mol of H_2 (g).

Space for Personal Notes

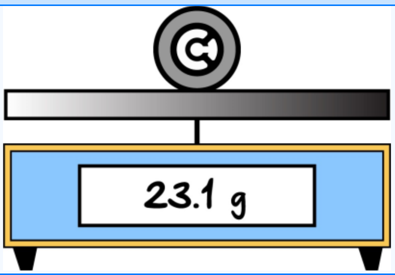
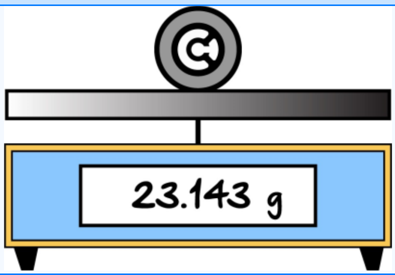
Sub-Section: Significant Figures

Context

- **So far:** giving our answers to a random number of decimal places
- **International System:** defines exact precision standards.

Discussion: How do we know how many decimal places our final answer should be to in any question?

Exploration: Significant Figures

Weighing Scale #1	Weighing Scale #2
 	
[more] / [less] precise	[more] / [less] precise
Can you claim weight is 23.14 g? [yes] / [no]	Can you claim weight is 23.14 g? [yes] / [no]

- **Level of Precision Used:** as precise as the [most] / [least] precise measurement
- **Link to Significant Figures:** use the [smallest] / [greatest] number of significant figures available in the question to express our answer.

Space for Personal Notes

Significant Figures

- **Definition:** Significant figures tell us how ____________________ a measurement is.

$$\underbrace{0.00}_{\text{Leading zeroes}}\ \overbrace{61}^{\text{Non-zero}}\ \underbrace{00}_{\text{in-between zeroes}}\ \overbrace{34}^{\text{Non-zero}}\ \underbrace{00}_{\text{Trailing zeroes}}$$

- **Rules:**
  - Non-zero digits: [significant] / [non-significant]
  - In-between zeros: [significant] / [non-significant]
  - Trailing zeros: [significant] / [non-significant]
  - Leading zeros: [significant] / [non-significant]
- **When Answering:** Use the [smallest] / [greatest] number of significant figures available in the question to express our answer.

Scientific Notation

- **Expression:** one **non-zero digit** to the **left** of the decimal, multiplied by a power of ten.
- Consider the following number:

$$6.1003400 \times 10^{-3}$$

  - **Correctly expressed in scientific notation:** [Yes] / [No]
  - **Number of significant figures:** ________

Space for Personal Notes

Let's look at some questions together!

Question 10 Walkthrough.

For each of the following questions, complete the associated table.

a. 100302

Current Number of Signifciant Figures	Expressed to 3 signficant figures

b. 0.023810

Current Number of Signifciant Figures	Expressed to 5 signficant figures

c. 1.99

Current Number of Signifciant Figures	Expressed to 2 signficant figures

Space for Personal Notes

Your Turn!

Question 11

Write each of the following to the number of significant figures indicated.

a. 10000 (2 sig figs)

b. 12345 (3 sig figs)

c. 0.0911 (2 sig figs)

Question 12

To calculate the number of atoms there are in 4.000 mol of calcium, state the number of significant figures your final answer should be to.

____

NOTE: Significant figures are accounted for using values in the question, as well as any Data Book values used!

Space for Personal Notes

Section B: Molar Mass

Sub-Section: Introduction to Molar Mass

We have now covered moles quite a bit, but we see that mass is slightly different to moles.

Discussion: If we have a carton of 1 dozen eggs, do we know how much it weighs ?

Exploration: Introduction to Molar Mass

- Consider different fruits:

6.02×10^{23} grapes	6.02×10^{23} apples
Amount (mol) present:	Amount (mol) present:

- **Amount:** [Same] / [Different]
- **Weight:** [Same] / [Different]

- Consider 10 of each fruit:
  - Each grape is 5 g, mass of 10 grapes: ____________________
  - Each apple is 200 g, mass of 10 apples: ____________________

- The collective mass of 10 apples is [greater] / [less] than the collective mass of 10 grapes.

- **Expression:** mass of a singular apple or grape:

Mass per Grape	Mass per Apple

- **Applied to atoms/molecules**: idea of ______________________________________ comes in.

Definition

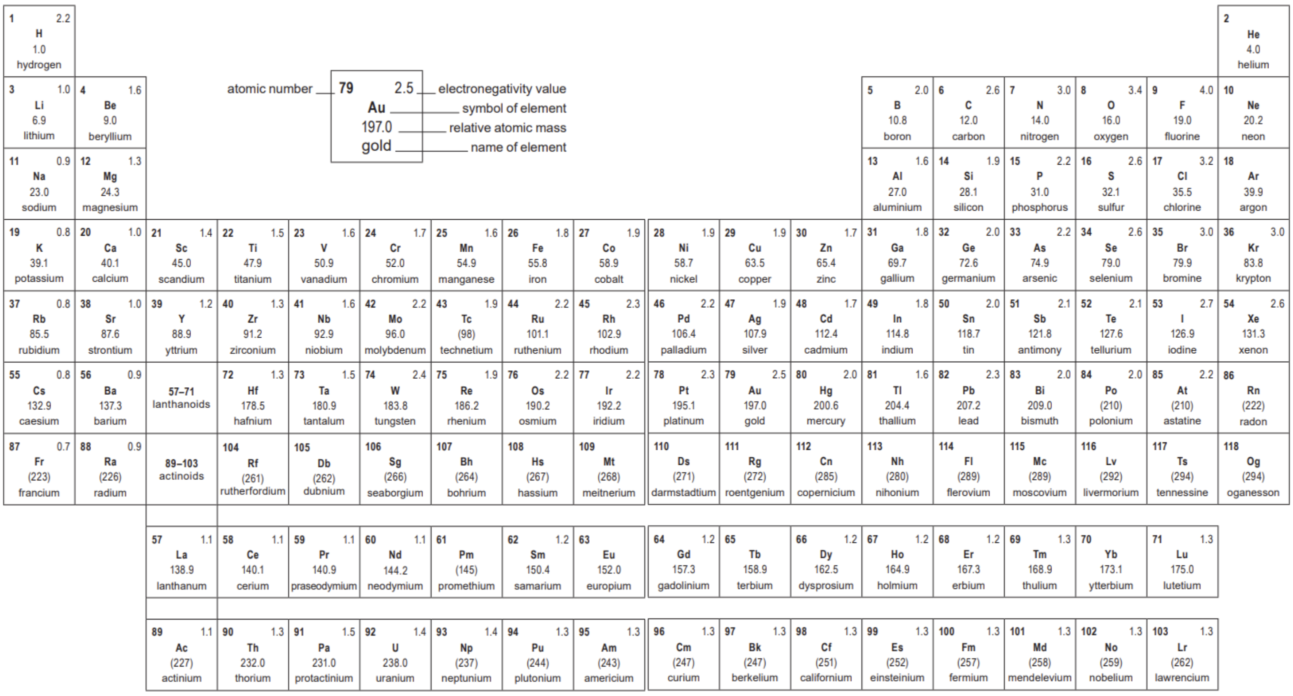
Molar Mass

- **Definition:**
  - The ratio between the mass (in g) and the amount of substance present (in mol).
  - It tells how heavy an atom/molecule is per mole.

SI Units	Denoted By:
g/mol	M or M_r

Databook

Molar Mass on the Periodic Table



- **Data Book:** page $12 - 14$
- For instance, looking at the Data Book:
  - **Molar mass of hydrogen:** ______________
  - **Molar mass of fluorine:** _______________
- We see that the molar mass of substances is dependent on its [atomic] / [mass] number

Discussion: **Why are some molar masses not whole numbers?**

Exploration: Chlorine Molar Mass

- Molar mass of chlorine (Cl)? __________________
- Does it have half a proton/neutron? [Yes] / [No]
- The 0.5 is obtained due to its __________________________ and its ____, which will be covered in the next booklet!

Let's look at some questions together!

Question 13 Walkthrough.

Find the molar mass of water (H_2O).

____

____

Question 14 Walkthrough.

Find the molar mass of sodium sulphate

NOTE: To obtain the molar mass of a substance, simply take the sum of the individual molar masses of all atoms which are contained in the substance.

Your Turn!

Question 15

Find the molar mass for the following molecules/compounds.

a. Hydrochloric acid (HCl)

b. Ammonia (NH_3)

Space for Personal Notes

Question 16

For each of the following ionic compounds, find its molar mass. Ensure to first find the formula of the compound

a. Barium phosphate

b. Ammonium dichromate

Question 17 Additional.

Find the molar mass of each of the following.

a. Hydrogen cyanide (HCN)

b. Aluminum sulphite

Space for Personal Notes

Sub-Section: Significant Figures for Addition & Subtraction

Context

- **So far:** significant figure rule for multiplication and division
- **Truth:** another convention for significant figures when adding or subtracting numbers

Exploration: Significant Figures for Addition & Subtraction

- Consider the following sum:

$$1.0 + 63.5$$

- **Significant Figures for First Number:** ________
- **Significant Figures for Second Number:** ________________
- **Significant Figures for Sum:** ______________
- **Supposed Final Answer:** _______________
- **Issue:** lost some precision through this process.
- **Solution:** Use the lowest number of _________________
- Consider the same sum again:

$$1.0 + 63.5$$

- **Decimal Places for First Number:** ___________
- **Decimal Places for Second Number:** _____________
- **Decimal Places for Sum:** ______________
- **Actual Final Answer:** __________________

Significant Figures for Addition & Subtraction

- When adding or subtracting multiple quantities, the final answer must be expressed to the lowest number of [significant figures] / [decimal places]

Try a question

Question 18

Complete the following tables, ensuring to express your answers to the correct number of significant figures

a. Hydrobromic acid (HBr)

Molar mass:	Number of significant figures in molar mass

b. Ammonia (NH_3)

Molar mass:	Number of significant figures in molar mass

Question 19 Additional.

State the molecular formula of a molecule whose molar mass would only have 2 significant figures.

Sub-Section: Using Molar Mass

Now that we've covered molar mass a little in depth, let's have a look at how to use it!

Exploration: Using Molar Mass

- What is the molar mass of carbon (C)? ______________
- This means for every one mole of carbon, it weighs __________ g!
- If we have two moles of carbon, how much will it weigh?
- **Formula:**
- **Formula Rearranged:**

$$n = \_\_\_\_\_\_\_\_$$

Molar Mass:

$$n = \frac{m}{M}$$

- Where:

Term	What it represents
N	is moles (in mol).
m	is mass (in g).
M	is molar mass (in g/mol).

Data Book: Page 3

Let's try a more challenging question!

Question 20 Walkthrough.

Jenny is investigating sulphur dioxide (SO_2), and has a vial containing 2.50 mol of it.

a. a) Calculate the mass of SO2 present.

b.

i. State the number of moles of oxygen atoms present.

ii. Hence or otherwise, determine the number of individual oxygen atoms present.

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TIP: Setting out Working Out

- When writing working out, there's a couple steps that you should follow:

1. Write out the ____________________ used (e.g., $n = \frac{m}{M}$).
2. _________________ to make what we're trying to find the subject (e.g., $m = n \times M$).
3. Write in ___________________ what atom/molecule/compound we're trying to find (e.g., $m(\mathrm{H_2O})$).
4. Write the actual ______________________ we are substituting into the formula (e.g., $m(\mathrm{H_2O}) = 10 \times 18$).
5. Write the answer.
6. Restate the answer in the correct number of _________________________

Let's do one more question together!

Question 21 Walkthrough.

Find the mass of 10.0×10^{24} molecules of carbon dioxide ($\mathrm{CO_2}$) in g.

____

____

____

____

____

TIP: If the question has multiple steps where we use values from previously used equations, make sure to use exact values (using the calculator), but you're allowed to write a rounded figure in your written working out.

Recall!

Active Recall: What are the 2 formulae which relate to moles?

Your Turn!

Question 22

Find the mass (in g) of each of the following amounts:

a. 8.90 mol of nitrogen dioxide gas (NO_2).

b. 9.51×10^{25} molecules of nitric acid (HNO_3).

Space for Personal Notes

Question 23 Additional.

Find the mass of 1 molecule of ammonium sulphate (made of $NH_4{}^+$ & $SO_4{}^{2-}$), in g.

Question 24 Additional.

Find the mass of 8.50 mol of sulphuric acid (H_2SO_4)

Question 25 Additional.

The formula of glucose is $C_6H_{12}O_6$. The mass of 1 mole of glucose will be, in g.

A. 30

B. 72

C. 144

D. 180

Space for Personal Notes

Now that we've covered the moles and molar mass formula, how do we find the number of moles from the mass?

Let's look at some questions together!

Question 26 Walkthrough.

49.0 g of copper sulphate, $CuSO_4$, was weighed out.

a. How many moles of $CuSO_4$ was weighed?

b. How many atoms of oxygen are present?

Space for Personal Notes

Your Turn!

Question 27

a. Determine the amount of sulfur, in mol, in $200\ g$ of sulfur.

b. Calculate the amount of sulfur, in mol, in 1.28×10^{25} atoms of sulfur.

Question 28

a. Calculate the molar mass of a substance, if you have $0.25\ mol$ of the substance in a $4.50\ g$ sample.

b. Give a suggestion for which molecule this is.

Space for Personal Notes

Question 29 Additional.

a. Determine the amount of oxygen, in mol, in 128 g of sulfur dioxide.

____

b. How many atoms of oxygen are there in 128 g of sulfur dioxide?

____

Question 30 Additional.

Which of the following represents the greatest number of mole of oxygen atoms?

A. 96 g of oxygen atoms.

B. 2.5 mole of ozone, O_3.

C. 2.4×10^{24} atoms of oxygen.

D. 72 g of water.

Space for Personal Notes

Section C: Different Units of Measurement

Sub-Section: Converting Between Units

Context

- **So Far:** Using SI units
- **Reality:** Have to use different units

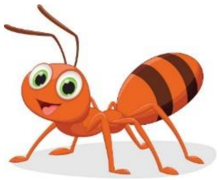
Discussion: Why do we use other units?

Exploration: Use of non-SI Units

Consider a human being:

- Weight units: ____________________

- Now consider an ant:



  - Weight units: ________________

- We use non-SI Units for ________________ purposes

To convert between these units, we can consult the Prefix Table!

Prefix Table

- Metric (including SI) prefixes.

Metric (including SI) prefixes	Scientific notation	Multiplying factor
giga (G)	10^9	$1\ 000\ 000\ 000$
mega (M)	10^6	$1\ 000\ 000$
kilo (k)	10^3	1000
deci (d)	10^{-1}	0.1
centi (c)	10^{-2}	0.01
milli (m)	10^{-3}	0.001
micro (μ)	10^{-6}	0.000001
nano (n)	10^{-9}	0.000000001
pico (p)	10^{-12}	0.000000000001

- **Data Book:** Page 4

Discussion: What units can you think of which starts with 'kilo-'?

Exploration: Prefixes

- Consider the units of kilometers and kilograms:
    - What do the letters represent? *(Label Below)*

km kg

- Meters in a kilometer (using own knowledge): ____________________
- Meters are in a kilometer (using Prefix Table): __________________________
- Consider the units of millimeters and milligrams:
    - What do the letters represent? *(Label Below)*

mm mg

- Meters are in a millimeter (using own knowledge): ____________________
- Meters in a millimetre (using Prefix Table): _____________________

Exploration: Converting Between Different Units

- Sometimes, units are given with some **prefix**, such as g vs kg vs mg vs μg.
- Always convert to the ______________ first when using equations!

How do we convert to SI Units?

- Converting: **Specific Unit → SI Unit**
  - **Method:** ____________________ by the number in the **(scientific notation) column**!
  - **Example**: Find the mass in grams of 3 kmol of H_2:

____

____

How do we convert to a specific unit?

- Converting: **SI Unit → Specific Unit**
  - **Method:** ____________________ by the number in the **(scientific notation) column**!
  - **Example**: Find the mass in ng of 8.75 mg of a substance:

____

____

TIP: Think about which unit is greater!

- Converting: **Larger Unit → Smaller Unit** (e.g. $kg \rightarrow g$)
  - Smaller unit is worth **[more]/[less]**, and thus there will be **[more]/[less]** of it for the same amount!
  - **Example:** from $kg \rightarrow g$, it is _________________.
- Converting: **Smaller Unit → Larger Unit** (e.g. $g \rightarrow kg$)
  - Larger unit is worth **[more]/[less]**, and thus there will be **[more]/[less]** of it for the same amount!
  - **Example:** from $g \rightarrow kg$, it is _________________.

Non-SI Units

- **Purpose:** to make more _______________ measurements of quantities
  - When going from a bigger to a smaller unit, there will be [more] / [less] of the same substance in the smaller unit, so we [multiply] / [divide] by the appropriate power of 10

Let's have a look at a question together!

Question 31 Walkthrough.

Find the mass in grams, if there are 7.30 pg of fluorine gas.

____

____

Question 32 Walkthrough.

Find the amount (in mol) of phosphate ions in 730 μg of calcium phosphate.

____

____

____

____

____

Space for Personal Notes

Your Turn!

Question 33

Some ionic compounds are investigated.

a. Find the amount of potassium ions, in mol, present in 2.0 kg of K_2SO_4.

b. Find the amount of hydrogen present, in mol, in 5.0 mg of $Ba(OH)_2$.

c. All three of the above salts are dropped into a beaker of water and stirred well. Identify the state of matter of all three of the salts.

Space for Personal Notes

Question 34 Additional.

The mass of calcium that has the same number of atoms as 20 g of helium will be closest to, in g.

A. 2

B. 40

C. 100

D. 200

Space for Personal Notes

Contour Check

☐ Learning Objective: [2.1.1] – Apply Avogadro's number to mole calculations using $n = \frac{N}{N_A}$

Study Design

Avogadro's constant as the number 6.02 × 10^{23} indicating the number of atoms or molecules in a mole of any substance; determination of the amount, in moles, of atoms (or molecules) in a pure sample of known mass

Key Takeaways

Moles

☐ **Definition:** The SI base unit for the ______________ of substance in chemistry

Denoted By	SI Units

☐ **Definition:** A **constant/number** which relates the number of [particles] / [grams] to the number of moles.

☐ N_A = ____________________

$$n = \_\_\_\_\_\_\_\_\_\_\_\_$$

☐ When determing moles of **atoms** from a **molecule:** must consider **ratios**

☐ Learning Objective: [2.1.2] Apply molar mass to mole calculations using $n = \frac{m}{M}$

Study Design

determination of the molar mass of compounds, the percentage composition by mass of covalent compounds, and the empirical and molecular formula of a compound from its percentage composition by mass

Key Takeaways

Molar Mass

☐ **Definition:**

- ○ The ratio between the mass (in g) and the amount of substance present (in mol).
- ○ It tells how heavy an atom/molecule is per mole.

SI Units	Denoted By:
g/mol	M or M_r

☐ Molar mass values can be found by considering the [atomic] / [mass] numbers of elements

Molar Mass:

$$n = \_\_\_\_\_\_\_\_\_\_$$

☐ Where:

Term	What it represents
N	is moles (in mol).
m	is mass (in g).
M	is molar mass (in g/mol).

☐ Learning Objective: [2.1.3] Apply unit conversions to calculation questions

Study Design

use appropriate chemical terminology, representations and conventions, including standard abbreviations, graphing conventions, algebraic equations, units of measurement and significant figures

Key Takeaways

Significant Figures

☐ **Definition**: Significant figures tell us how __________________________ a measurement is.

$$\underbrace{0.00}_{\text{Leading zeroes}}\;\overbrace{61}^{\text{Non-zero}}\;\underbrace{00}_{\text{in-between zeroes}}\;\overbrace{34}^{\text{Non-zero}}\;\underbrace{00}_{\text{Trailing zeroes}}$$

☐ **Rules:**

☐ Non-zero digits: [significant] / [non-significant]

☐ In-between zeros: [significant] / [non-significant]

☐ Trailing zeros: [significant] / [non-significant]

☐ Leading zeros: [significant] / [non-significant]

☐ **When Answering:** Use the [smallest] / [greatest] number of significant figures available in the question to express our answer.

Scientific Notation

☐ **Expression:** one **non-zero digit** to the [left] / [right] of the decimal, multiplied by a power of ten.

☐ When adding or subtracting multiple quantities, the final answer must be expressed to the lowest number of [significant figures] / [decimal places]

Non-SI Units

- ☐ **Purpose:** to make more ______________ measurements of quantities
- ☐ When going from a bigger to a smaller unit, there will be [more] / [less] of the same substance in the smaller unit, so we [multiply] / [divide] by the appropriate power of 10

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