CHEM 1101B- Chemistry for Engineers

Professor: Alisha Szozda (she/her)
Email: alishaszozda@cmail.carleton.ca

HS (Health Sciences) 1301
Mondays & Wednesdays 8:35am - 9:55am

Lecture 1: Introduction + Sig Figs

Welcome to the course!

Please feel free to introduce yourself to your neighbors– name, pronouns, a hobby, etc.

and/or

Complete Metacognitive assessment on Brightspace if you haven’t completed it yet


YOU ARE WELCOME
HERE

Carleton University

PARTICIPATE IN A RESEARCH STUDY IN CHEM1001/1101

Help us understand factors that impact success & resilience in large first-year Chemistry classes!

What is this study about?

First year chemistry is required by many STEM programs and is often considered a challenging course due to the higher rates of failure/withdrawal. This study aims to better understand factors that influence students' performance in first-year chemistry classes.

Why should you participate?

Your participation will help us better understand the factors that impact your success in this course. With improved understanding, we can develop targeted interventions to support student success in first year chemistry courses.

Who can participate?

All students in CHEM1001 (A, B & E) CHEM 1101 (A & B) are eligible to participate.

Participants will be entered to win one of 20 Amazon gift cards valued at $25 each.

Click here to participate!

Contact Information:

Should you have any questions, please feel welcome to email millie.close@carleton.ca.

This study has been cleared by the Carleton University Research Ethics Board B Clearance #121640

If you have any ethical concerns with the study, please contact the Carleton University Research Ethics Board, preferably by email at ethics@carleton.ca or you can leave a message by phone at 613-520-2600 ext. 2517.

Complete the Research Questionnaire here:

Carleton University

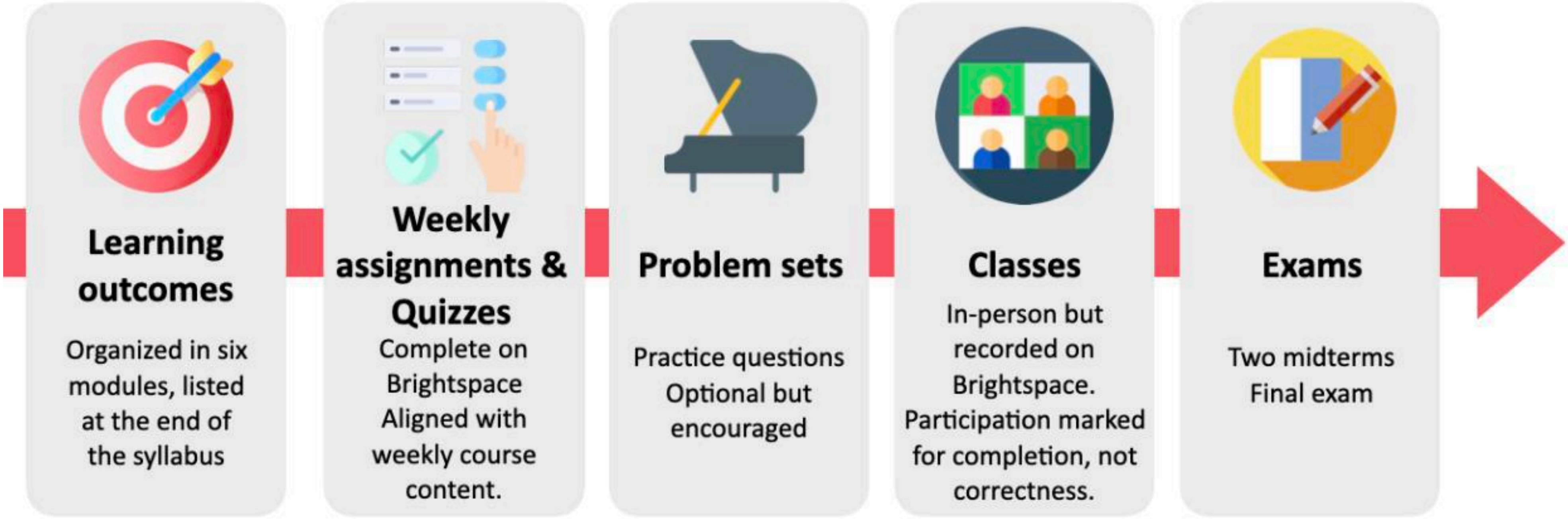
A little about me…

FRG
FLYNN RESEARCH GROUP

https://www.flynnresearchgroup.com/

- Education:
  - PhD in Chemistry Education Research, University of Ottawa
  - BSc Honours in Chemistry, Queens University
  - BEd, Queens University
- Equity, Diversity, and Inclusion & mental health advocate
- Love spending time outdoors: biking, hiking, skiing
- Dog lover: Dog mom to Otto the cockapoo

Course format



In-class participation: Wooclap

You can choose to actively participate in class through problem-solving, asking and answering questions, and having discussions with your peers to receive **1% extra credit toward your final grade**.

You can participate in class in two ways:
1. ***Synchronously*:** Do the class activities while you are in the live class; I'll give instructions as we go along.

OR

2. ***Asynchronously***: Submit the answers to the class questions in the "Class participation" space in Brightspace within 48 hours of the end of class.

Either way, submissions are marked for completion, not correctness. You need to participate in 80% of classes (synchronously or asynchronously) to receive the full participation extra credit mark; there's no need to tell me if/why you miss a class.

Let's give it a try!!

What Engineering program are you enrolled in? wooclap

Access questions through the link in **Brightspace > Content > Wooclap**,
or go to **wooclap.com** and enter code ___YCDZUM___ in event code banner.
(You must log in through your CarletonU account.)

Summary of Assessments

Laboratory	Assignments	Quizzes	Two midterms	Final exam
25%	10%	10%	20% (10% each)	35%
Operates separately from theory section of course but will be included in final grade, see details below	Weekly Due **FRIDAYS, 11:55PM** ET Complete on Brightspace **Drop lowest 4** **Best 13/17 count**	Weekly Due **FRIDAYS, 11:55PM** ET Complete on Brightspace **Drop lowest 4** **Best 13/17 count**	**October 9th** and **November 20th** **8:35 - 9:55 am,** ET In-person, in-class closed book exam	**Date to be determined** In-person, scheduled by university closed book exam

Extra Credit

Up to 3%

Diagnostic quiz and metacognitive assessments (1%)
Participation (1%)
Green Chemistry Applications (1%)

Grading Scheme (s)

	OPTION 1	OPTION 2	OPTION 3
LABORATORY	25%	25%	25%
ASSIGNMENTS	10%	--	--
QUIZZES	10%	--	--
MIDTERMS	20%	20%	--
FINAL EXAM	35%	55%	75%
BONUS ASSIGNMENTS	3%	3%	3%

** FINAL EXAM: You **must** get 40% or higher to pass the course.

** LABS: They are **mandatory**; incomplete = F in the course

Lab schedule

Date Performed	Lab Component	Group
September 12-13	Academic Inegrity/Check-in/Techniques	A, B, C, D
September 19-20	Academic Inegrity/Check-in/Techniques	E, F, G, H
September 26-27	Fe	A, B, C, D
October 3-4	Fe	E, F, G, H
October 10-11	G	A, B, C, D
October 17-18	G	E, F, G, H
October 21-25	Winter Break No Classes	-----
Oct. 31-Nov. 1	Cal	A, B, C, D
November 7-8	Cal	E, F, G, H
November 14-15	AB	A, B, C, D
November 21-22	AB	E, F, G, H

Being successful in this course

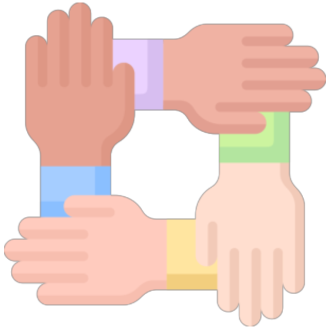
Show up to class, come prepared and be ready to participate!

Make a strategic plan!

Regularly check Brightspace & practice lots!

Make note of due dates for, assignments, topic quizzes, midterms etc!

Your physical and mental health matter!



Connect with others in the course

Communication in this course

Before/after class

Using the chat or in person. I try to have 15 minutes available before and after each class.

Email

Use for confidential messages. Please put CHEM1101B in the subject line. I do my best to respond within one business day.

Student hours

During student hours (formerly known as office hours), you can ask questions or simply listen.

Questions - Slack

Slack is a good place to ask general questions about the course concepts or structure. You can get the app or work in a browser.

Meeting

If the other ways don't work for you, please connect me via email to arrange a one-on-one meeting over zoom

Announcements

Please check Brightspace announcements regularly and/or turn on notifications. This is where I post key information.

Questionnaires

I'll ask you for information and suggestions periodically, so that I can optimize the course and adjust as we go.

TAs

You can ask TAs questions via email or connect in Slack.

Course questions? Ask on Slack

We will be using Slack as an online platform to connect with othe classmates and ask questions about course concepts.

- Username MUST be first/last name.
- Be respectful
- Academic code of conduct applies in online spaces

Course questions? Come to student hours

Timeslot	Monday	Tuesday	Wednesday	Thursday	Friday
08:35-09:25	257	65	257	85	121
09:35-10:25	257	106	257	126	128
10:35-11:25	113	105	119	132	128
11:35-12:25	85	226	122	220	99
12:35-13:25	87	230	145	224	101
13:35-14:25	47	119	121	179	121
14:35-15:25	165	160	86	143	147
15:35-16:25	163	160	170	143	151
16:35-17:25	88	167	162	83	60
18:05-18:55	11	72	23	66	2
19:05-19:55	11	74	8	92	0
20:05-20:55	6	74	8	92	0
21:05-21:55	0	0	0	74	0

Mondays

1:30 – 2:30 PM

~~SC 115~~

Steacie

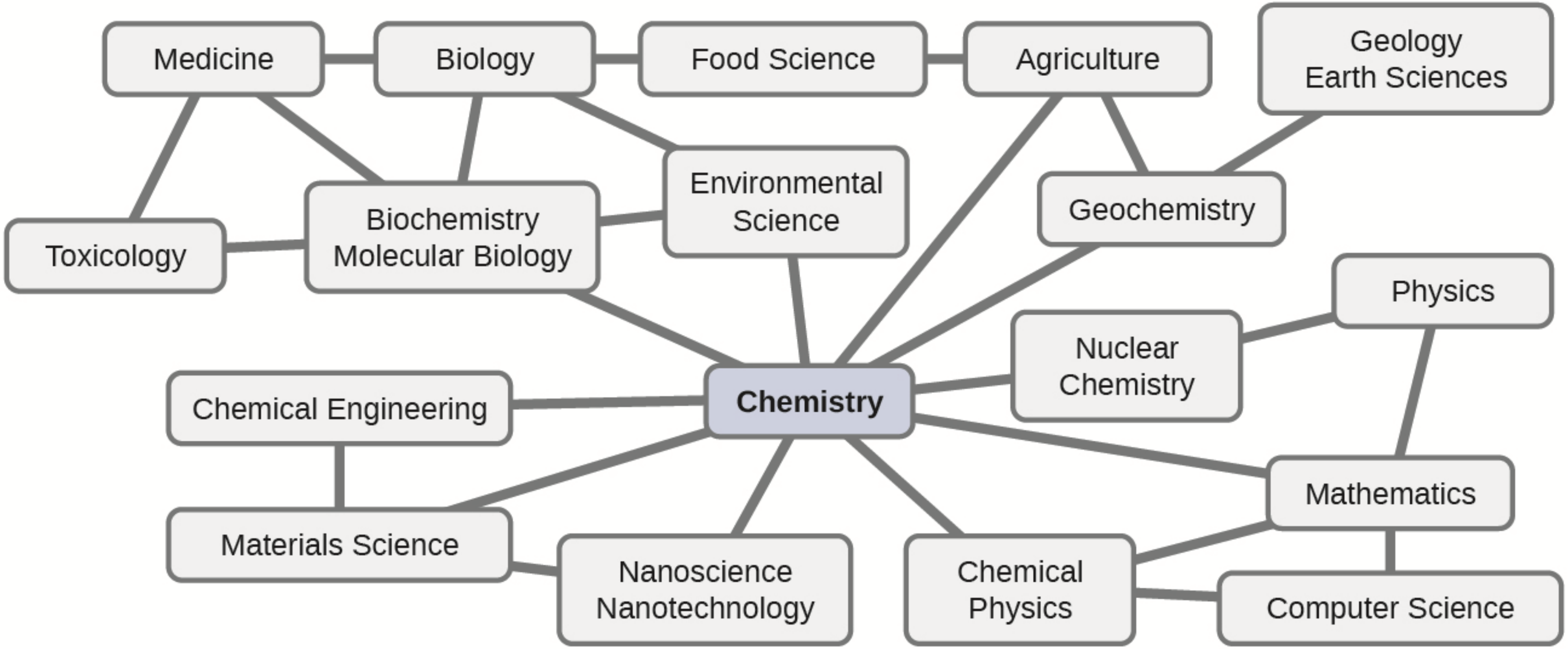
Most students are free during this time.

If that time doesn't work, email me to schedule a 1-on-1

Need extra help?

Knowledge of chemistry is central to understanding a wide range of scientific disciplines

"Chemistry deals with the composition, structure, and properties of matter, and the ways by which various forms of matter may be interconverted."

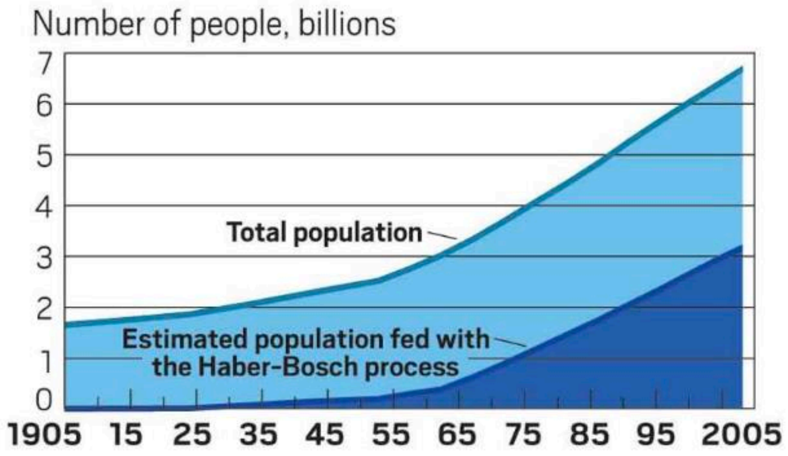


https://chem.libretexts.org/Courses/College_of_the_Canyons/Chem_201%3A_General_Chemistry_I_OER/01%3A_Matter_and_Measurements/1.01%3A_Chemistry-_The_Central_science

A central learning outcome for chemistry

"Chemicals have benefits and hazards, and these must be considered together"

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$$



Without the Haber-Bosch process, about half the world's population wouldn't have enough food.

Source: *Nat. Geosci.* 2008, DOI: 10.1038/ngeo325.

Note: Data after 2008 are estimates.

GREEN CHEMISTRY

Industrial ammonia production emits more CO_2 than any other chemical-making reaction. Chemists want to change that

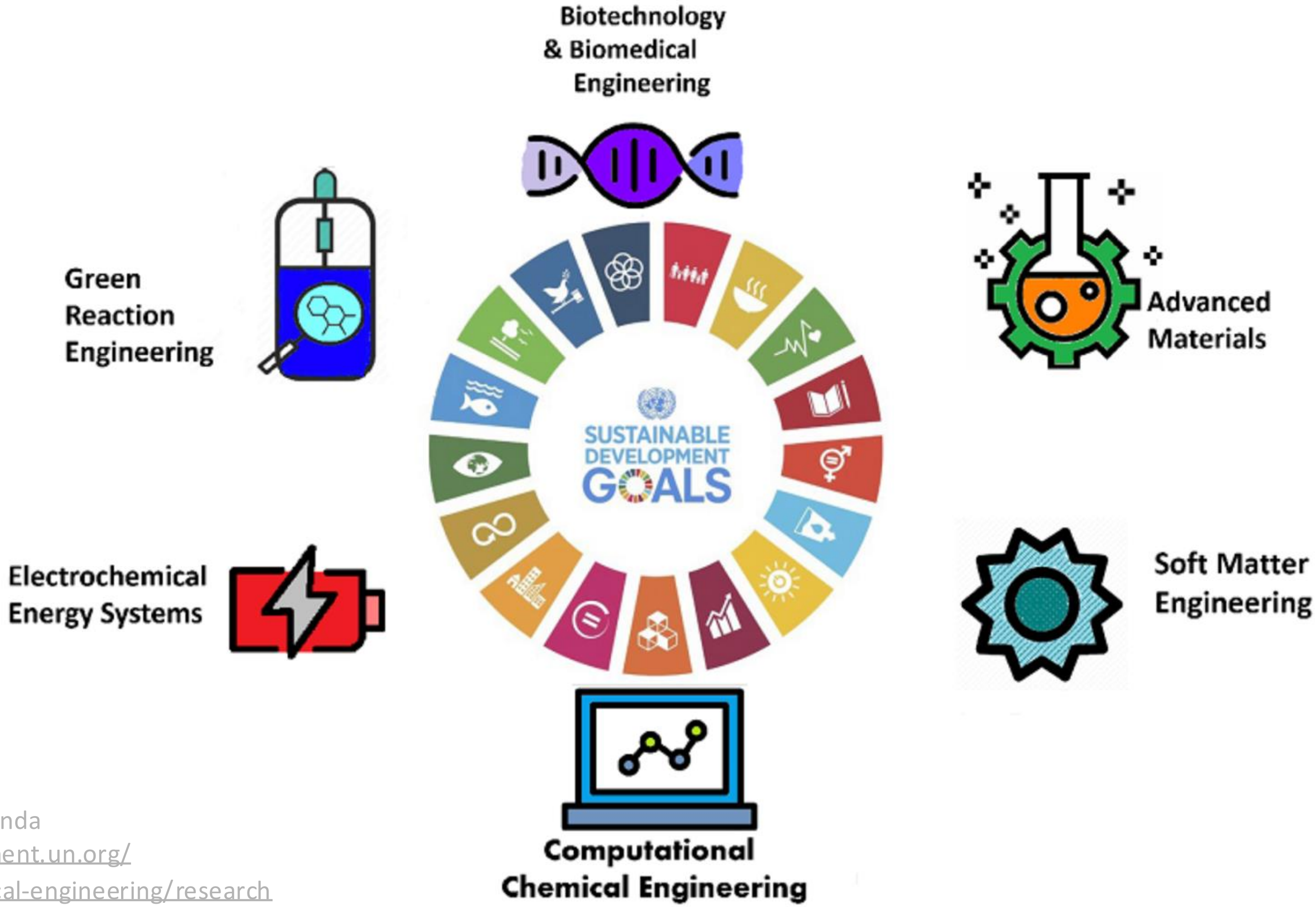
Scientists around the world are working to reduce how much greenhouse gas the ammonia-making process emits

by ***Leigh Krietsch Boerner, special to C&EN***

June 15, 2019 | A version of this story appeared in **Volume 97, Issue 24**

https://cen.acs.org/environment/green-chemistry/Industrial-ammonia-production-emits-CO2/97/i24
https://cen.acs.org/food/agriculture/The-industrialization-Haber-Bosch-process/101/i26

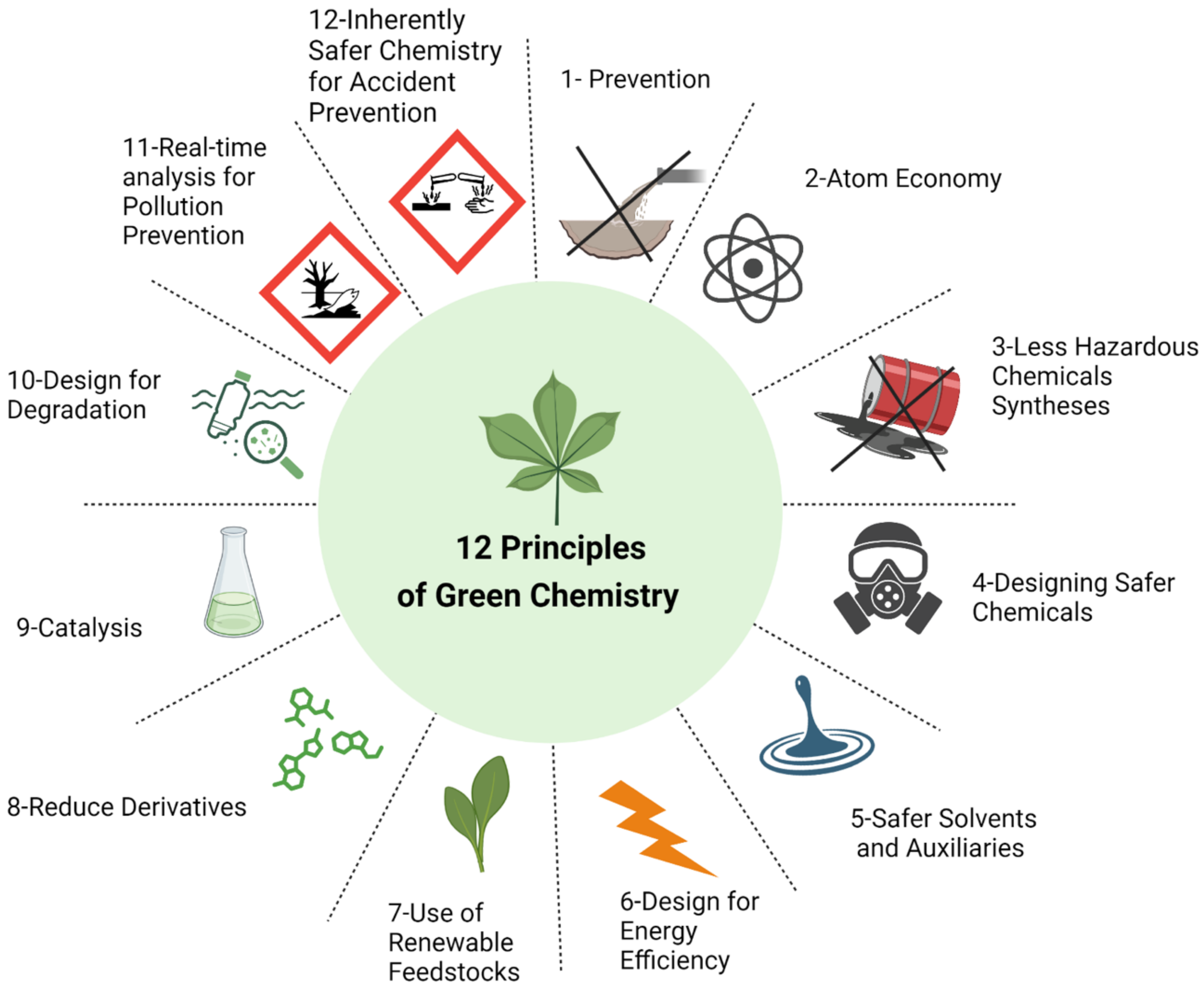
Chemists and Engineers are trying to make chemical syntheses more sustainable!



https://sdgs.un.org/2030agenda
https://sustainabledevelopment.un.org/
https://uwaterloo.ca/chemical-engineering/research

Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.

Green chemistry applies across the life cycle of a chemical product, including its design, manufacture, use, and disposal.



https://www.epa.gov/greenchemistry/basics-green-chemistry
Anastas, P., & Warner, J. (1998). 12 Principles of Green Chemistry. American Chemical Society.
https://www.acs.org/greenchemistry/principles/12-principles-of-green-chemistry.html

Overarching learning outcomes for this course

- Apply core chemical concepts and processes to solving complex problems in the real world
- Describe macroscopic properties of chemical substances and explain how atomic or molecular behaviour accounts for those properties, including in everyday situations.
- Appreciate the interdisciplinary nature of chemistry and relate chemical concepts to problems in other disciplines
- Construct scientific arguments in chemistry, using evidence and causal reasoning to support a claim—these arguments relate to any question where you are asked to explain "why" or to "justify" your response
- Use green chemistry principles to calculate environmental impact-based metrics in chemistry to compare how environmentally friendly one thing/decision is compared to another
- Use inclusive language and behaviour in all aspects of the course, including classes and assessments (to be self-assessed)

Learning outcomes for Math and Measurement Topic

- Calculate with values in standard or exponential/scientific notation (on a calculator)
- Relate the number of digits reported in a measured or calculated value to the precision of the original measurement(s)
- Report your own calculated values to the appropriate number of significant figures
- Determine how many significant figures are in a measured value
- Determine the position of the significant figures in a measured value
- Determine how many significant figures are in the result of a calculation that involves at least one measured value

Scientists and Engineers work with very large and small numbers all the time!

3.14159 26535 89793 23846 26433 83279 50288 41971 69399 37510

Now that's a hard number to work with!

But what if you are an engineer and you need precise calculations?

Solution! Rewrite numbers to make them easier to work with

Exponential and Scientific Notation

Scientific/exponential notation: writing numbers based on powers of 10

- Always has one number (non-zero digit) to the left of the decimal point

Significand = the non-zero portion of the value

Exponent = the power of ten you have to multiply the significand by to give the true magnitude (size) of the value

The speed of light in a vacuum:

299 800 000 m/s (or *about* 300 000 000 m/s)

$$c = 2.998 * 10^{8}\ \mathrm{m\ s^{-1}}$$

significand exponent

Converting Standard to Scientific Notation

- To determine the exponent, count the number of times you "bounced" the decimal place (remember, if there was no decimal in the original, its actual position was at the end!)
- Each "bounce" represents multiplying or dividing by 10

Large numbers = positive exponent

N_A = 60 200 000 000 000 000 000 000. $\qquad$ $N_A = 6.02 \times 10^{23}$

x10

Small numbers = negative exponent (tip: count the zeros left of decimal point)

h = 0.000 000 000 000 000 000 000 000 000 000 000 0626 J s

÷10

$h = 6.626 \times 10^{-34}$ J·s

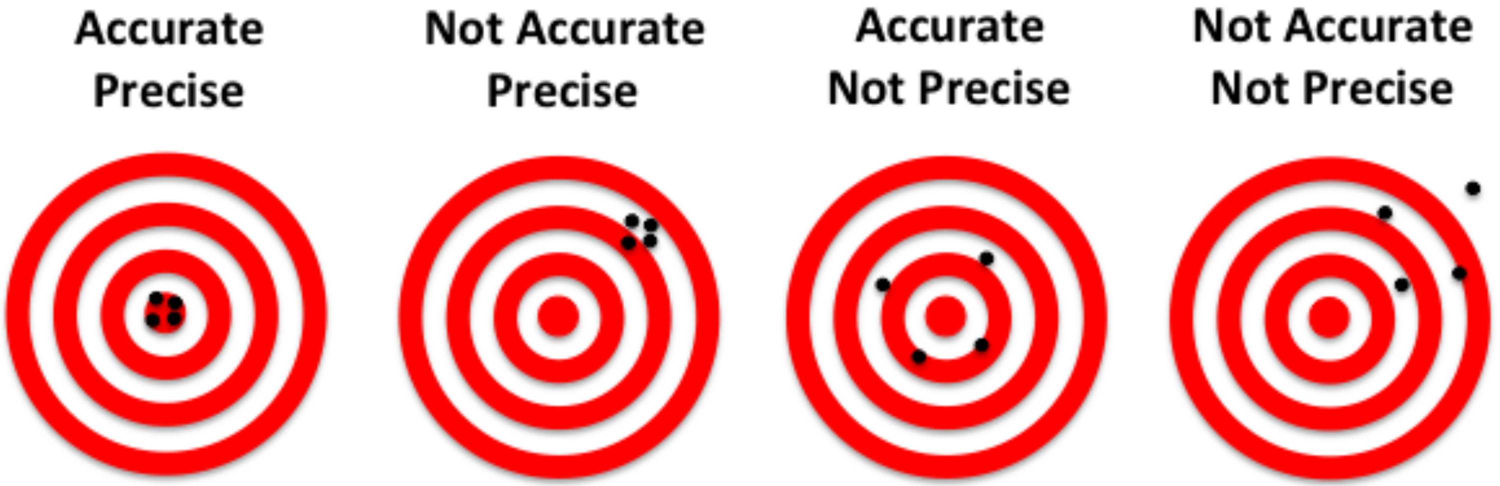
Scientific notation is useful for very large and small numbers but…

It is also extremely important in allowing us to indicate **significant figures** in a clear and unambiguous way.

What are significant figures?

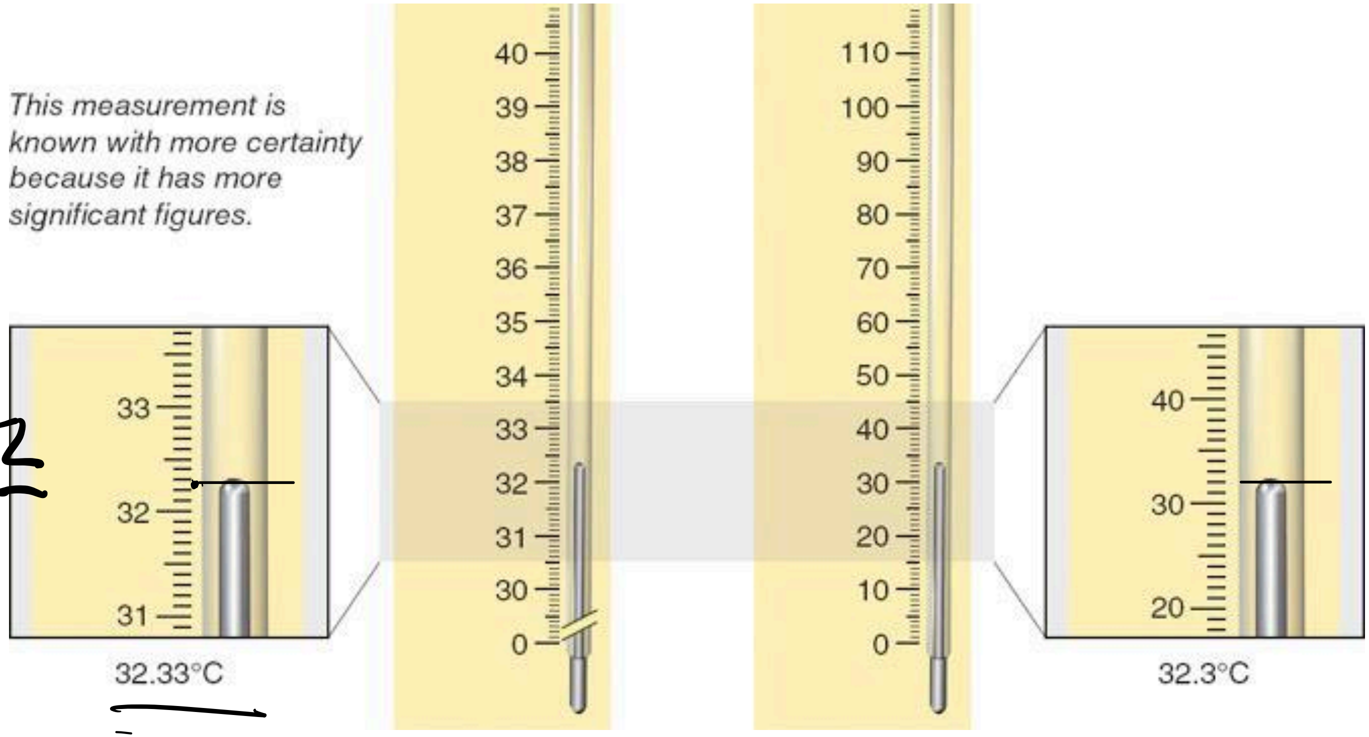
Significant figures tell you how ***precisely*** a *measured* value is known but don't tell you anything about ***accuracy***. (how closely a measured value is to the true value)

- only have meaning for *measured* values



All measurements have uncertainty

- the last digit is the uncertain digit
- the number of sig figs in a measurement includes both certain and uncertain digits!



32.33 ± 0.02
4 s.f.

32.3 ± 0.2 °C
3 s.f.

General Rules for Sig Digs

3 s.f.
2.45 All non-zero numbers are **significant**

4 s.f.
2.405 Zeros between non-zero numbers are **significant**

5 s.f.
2.4050 Zeros to the right of the decimal point are **significant** (includes trailing zeros)

2 s.f.
24~~00~~ Zeros with no decimal point are **NOT significant**

2 s.f.
~~0.000~~24 Leading zeros are **NOT significant**

$2.40*10^{-4}$ Hint: scientific notation can be used to give appropriate number of sig digs

Learning Check 1: Sig Digs in the Lab

wooclap

The specifications for a 100 mL volumetric flask state that it is guaranteed to contain the specified volume to within 0.1 mL. How many significant figures should you use to record the volume contained in the flask?

A) 1
B) 2
C) 3
D) 4

✓

$100.0 \pm 0.1\,mL$

1 2 3 4

Sig Digs and Lab Precision

equipment	capacity	uncertainty
grad cylinder	10 ml	± 0.1 ml
	100 ml	± 0.2 ml
transfer pipet	5 ml	± 0.01 ml
	10 ml	± 0.02 ml
	25 ml	± 0.03 ml
Mohr pipet	10 ml	± 0.05 ml per reading
(calibrated)	250 ml	± 0.12 ml per reading
buret (cls B)	50 ml	± 0.05 ml per reading
vol flask	10 ml	± 0.02 ml
	25 ml	± 0.03 ml
	50 ml	± 0.05 ml
	100 ml	± 0.08 ml
	250 ml	± 0.12 ml
	500 ml	± 0.15 ml
thermometer	-10 to 110 C	± 0.2 C
balance	top load	± 0.01 g
	analytical	± 0.0001 g

Sig Figs in Calculations

Addition and Subtraction:

- When adding or subtracting, you only count sig figs *relative* to the decimal point
- Answer has the same number of decimal places as the measurement with the **fewest decimal places**

Multiplication and Division:

- Answer has the same number of sig figs as the measurement with the **fewest sig figs**

Correct the answers for each example:

52.012mg +751mg = 803.~~012~~mg

3 dec. 0 dec. 803mg

2.06mL -1.1mL = 0.96mL = 1.0mL ✓

2 dec. 1 dec. ~~0.1mL~~

incorrect from lecture!

152m * 2 s^{-1} = 304 m/s

3 s.f. 1 s.f. 3×10^2 m/s

152m / 55s = 2.763 m/s

3 s.f. 2 s.f. 2.8m/s

Adding or Subtracting Values in Scientific Notation

You have to modify the scientific notation as needed so that all the exponents have the ***same*** value (you don't need to convert them into standard notation!)

The simplest strategy:

step 1.

1) Add them up on a calculator
2) Convert all of the values into the same exponent as the exponent in the answer you get

9.624793	$\times 10^{-24}$	kg
7.439	$\times 10^{-25}$	kg
6.2	$\times 10^{-28}$	kg
[1.0369313	$\times 10^{-23}$]	kg

$0.9624793 \times 10^{-23}$

0.07439×10^{-23}

$0.0000062 \times 10^{-23}$

$1.0369313 \times 10^{-23}$

$\approx 1.03693 \times 10^{-23}$

Sig Figs and Rounding

- In calculations, carry through one or two extra significant digits
  - Always round at the end!
- Round up if first digit to be eliminated is 5 or higher
- Round down if first digit eliminated is less than 5

2 dec. 1 dec.

Example: $\frac{25.65\ mL + 37.4\ mL}{73.55\ s\ (\frac{1\ min}{60\ s})} = \frac{63.05\ mL}{1.2258\ min}$ 3 s.f. 4 s.f.

4 s.f.

Exact # does not affect sig figs.

$= 51.436\ \frac{mL}{min}$ round down.

$= 51.4\ mL/min$

3 s.f.

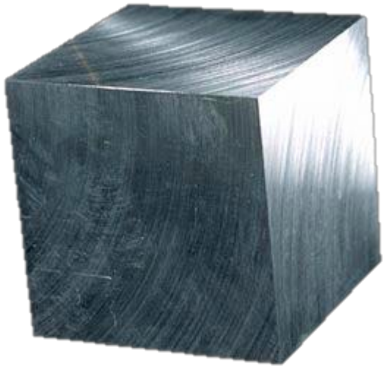
Sig Figs and Rounding: Example

homework.

3 sig figs

4 sig figs

A small cube of aluminum measures 15.6 mm on a side and has a mass of 10.25 g. What is the density of aluminum in g/cm^3?



① Unit conversion

10mm = 1 cm

$$15.6\text{mm} \times \frac{1\text{cm}}{\underbrace{10\text{mm}}_{\text{doesn't count for sig figs}}} = 1.56\text{ cm}$$

② Calculation

$$\delta = \frac{m}{V}$$

4 sig figs

$$= \frac{10.25\text{g}}{(1.56\text{cm})^3}$$

3 sig figs

$$= 2.69914\ \frac{\text{g}}{\text{cm}^3}$$

Answer must have 3 sig figs

round up!

$$\approx 2.70\ \text{g/cm}^3$$

Learning Check 2: Sig Digs and Rounding

wooclap

5 s.f. 5 s.f.

The result of (3.8621 x 1.5630) - 5.98 is properly written as:

A) 0.06
B) 0.056
C) 0.0565
D) 0.05646
E) 0.056462

$(\underbrace{6.03646}_{\text{4 dec.}}) - \underbrace{5.98}_{\text{2 dec.}}$

round up

≈ 0.05646

≈ 0.06

Exact Numbers

1. Numbers that are ***counted***

e.g. *the number of students in the room*

2. Numbers that serve as ***mathematical operators***

e.g. *in the equation*

$$\ln\left(\frac{x}{1.86}\right) = \frac{284.2 \times 103}{8.314}\left(\frac{1}{392.6} - \frac{1}{437.0}\right)$$

3. Numbers that are ***defined***:

e.g. *by convention, there are* ***exactly*** *2.54 cm in an inch.*

Unit prefix conversions:

e.g. k (as in **kilo**meter) is exactly 1000

p (as in **pico**meter) is exactly 10^{-12}

Exact Numbers

Exact numbers are treated as if they have:

- An infinite number of significant digits
- An infinite number of decimal places

This means that exact numbers never limit the number of significant digits in a result.

Exact Numbers: Example

When multiplying by exact numbers, **addition rules apply (no sig fig rules)**, because if you have three golf balls, and each golf ball weighs 44.82 grams, you're really saying "add this value three times":

$$
\begin{array}{rr}
 & 44.82\text{ g} \\
+ & 44.82\text{ g} \\
+ & 44.82\text{ g} \\
\hline
 & 134.46\text{ g}
\end{array}
$$

Logarithms ($\log_{10}$ & ln)

Logarithm: The power to which 10 must be raised to restore the original value.

e.g. 1000. (= 10 x 10 x 10) = [10^3]

Since you have to raise 10 to the power of 3 to get your "1000." back,

The log of 1000. is 3

$\log_{10}$ (1000.) = 3

Where does the three come from?
Was it part of the sig figs originally?
How many sig figs were there originally?

Logarithms ($\log_{10}$ & ln)

Significant figure rule for logs and ln's:

- Determine the number of sig figs in the original value

- Keep this many **decimal places** in the calculated log or ln.
  - Keep any digits in front of the decimal place, but don't count them as sig figs
  - Add zeros on the end of the value if you don't have enough sig figs already

$$\log_{10}(1000) = 3 \qquad =$$

$$\log_{10}(1000.) = 3 \qquad =$$

$$\log_{10}(9.85 * 10^{-31}) = -30.000656377 \quad =$$

Logarithms ($\log_{10}$ & ln)

wooclap

Taking antilogs & antilns:

- The number of sig figs **after the decimal place** represents the total number of sig figs in the calculated result.

How many sig figs should be reported for each calculated result?

1. $\log_{10}(x) = 4.939 \quad x = 86,896.024293$
2. $\ln(x) = 0.6 \quad x = 1.8221188$
3. $pH = 14.27 \quad [H^+] = 5.3703179 * 10^{-15}$

Sig figs & lab precision

1. You weigh 9.5328 g of sodium chloride on an analytical balance, and dilute it to 500.0 ml in a volumetric flask.
2. You pipette 10.00 ml of this solution into a 250.0 ml volumetric flask and dilute it to the mark.
3. You use a 10.00 ml Mohr pipette to dispense 7.63 ml of this solution.

How many moles of sodium chloride did you dispense?

sodium	chlorine
11	17
Na	Cl
22.990	35.45

Molar Mass NaCl:58.44 g/mol

Sig figs & lab precision

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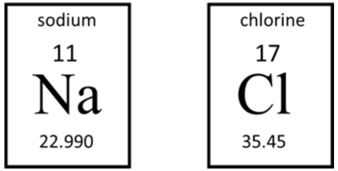

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How many moles of sodium chloride did you dispense?

How do we calculate the uncertainty for this final value of moles?

1. 9.5328 g ± 0.0001 g (analytical balance)
   500.0 ml ± 0.15 ml (volumetric flask)
2. 10.00 ml ± 0.02 ml (transfer pipette)
   250.0 ml ± 0.12 ml (volumetric flask)
3. 7.63 ml ± 0.05 ml (Mohr pipet)

equipment	capacity	uncertainty
grad cylinder	10 ml	± 0.1 ml
	100 ml	± 0.2 ml
transfer pipet	5 ml	± 0.01 ml
	10 ml	± 0.02 ml
	25 ml	± 0.03 ml
Mohr pipet	10 ml	± 0.05 ml per reading
(calibrated)	250 ml	± 0.12 mlper reading
buret (cls B)	50 ml	± 0.05 ml per reading
vol flask	10 ml	± 0.02 ml
	25 ml	± 0.03 ml
	50 ml	± 0.05 ml
	100 ml	± 0.08 ml
	250 ml	± 0.12 ml
	500 ml	± 0.15 ml
thermometer	-10 to 110 C	± 0.2 C
balance	top load	± 0.01 g
	analytical	± 0.0001 g

Sig figs & lab precision

Relative percent uncertainty = (absolute uncertainty)/(measured value)·100%

	Measured Value (n)	Absolute Uncertainty (σ)		Relative percent Uncertainty ($\frac{\sigma_n}{n}$)
1.	9.5328 g	± 0.0001 g	(analytical balance)	0.00104 %
	500.0 ml	± 0.15 ml	(volumetric flask)	0.03 %
2.	10.00 ml	± 0.02 ml	(transfer pipette)	0.2 %
	250.0 ml	± 0.12 ml	(volumetric flask)	0.048 %
3.	7.63 ml	± 0.05 ml	(Mohr pipette)	0.655 %

How many moles of sodium chloride did you dispense? $\boxed{}$ $\pm$ $\boxed{}$

Error propagation equation

Addition or subtraction

$$F = x_1 \pm x_2 \pm x_3 \pm \cdots \ldots$$

$$\sigma_F = \sqrt{(\sigma_{x_1})^2 + (\sigma_{x_2})^2 + (\sigma_{x_3})^2 + \cdots}$$

Multiplication or division

$$F = x_1 * x_2 \div x_3 * \cdots \ldots$$

$$\frac{\sigma_F}{F} = \sqrt{\left(\frac{\sigma_{x_1}}{x_1}\right)^2 + \left(\frac{\sigma_{x_2}}{x_2}\right)^2 + \left(\frac{\sigma_{x_3}}{x_3}\right)^2 + \cdots}$$

Calculating uncertainty using error propagation

1. $\boldsymbol{m_i}$ = 9.5328 g ± 0.0001 g — 0.00104 %
   $\boldsymbol{V_0}$ = 500.0 ml ± 0.15 ml — 0.03 %
2. $\boldsymbol{V_1}$ = 10.00 ml ± 0.02 ml — 0.2 %
   $\boldsymbol{V_2}$ = 250.0 ml ± 0.12 ml — 0.048 %
3. $\boldsymbol{V_3}$ = 7.63 ml ± 0.05 ml — 0.655 %

How many moles of sodium chloride did you dispense?

$$\mathrm{n} = \frac{\mathrm{V_1} * \mathrm{m_i} * \mathrm{V_3}}{\mathrm{MW} * \mathrm{V_0} * \mathrm{V_2}}$$

$$\frac{\sigma_n}{n} = \sqrt{\left(\frac{\sigma_{m_i}}{m_i}\right)^2 + \left(\frac{\sigma_{V_0}}{V_0}\right)^2 + \left(\frac{\sigma_{V_1}}{V_1}\right)^2 + \left(\frac{\sigma_{V_2}}{V_2}\right)^2 + \left(\frac{\sigma_{V_3}}{V_3}\right)^2 + \left(\frac{\sigma_{MW}}{MW}\right)^2}$$

$$\frac{\sigma_n}{n} = \sqrt{(0.00104\%)^2 + (0.03\%)^2 + (0.2\%)^2 + (0.048\%)^2 + (0.655\%)^2 + (0\%)^2}$$

$$\frac{\sigma_n}{n} = 0.682\%$$