

# SI Chemistry - Full Discipline Demo

## Laboratory Techniques and Measurements

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### Final Report - Answer Guide

|                    |                                     |
|--------------------|-------------------------------------|
| <b>Institution</b> | Science Interactive University      |
| <b>Session</b>     | SI Chemistry - Full Discipline Demo |
| <b>Course</b>      | SI Chemistry - Full Discipline Demo |
| <b>Instructor</b>  | Sales SI Demo                       |

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### Test Your Knowledge

**Rank the measurements in order from smallest to largest.**

≡  $1.0 \times 10^{-5} \text{ m}$

1 **Correct answer:**  $3.0 \times 10^{-7} \text{ m}$

≡  $2.0 \times 10^{-6} \text{ m}$

2 **Correct answer:**  $2.0 \times 10^{-6} \text{ m}$

≡  $3.0 \times 10^{-7} \text{ m}$

3 **Correct answer:**  $1.0 \times 10^{-5} \text{ m}$

≡  $4.0 \times 10^3 \text{ mm}$

4 **Correct answer:**  $1.0 \text{ m}$

≡  $1.0 \text{ m}$

5 **Correct answer:**  $4.0 \times 10^3 \text{ mm}$

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Match each SI base unit to the appropriate measurement.

|            |               |             |             |                    |                         |
|------------|---------------|-------------|-------------|--------------------|-------------------------|
| ⌘ kelvin   | <b>Length</b> | <b>Mass</b> | <b>Time</b> | <b>Temperature</b> | <b>Amount of Matter</b> |
| ⌘ kilogram | 1             | 2           | 3           | 4                  | 5                       |
| ⌘ meter    |               |             |             |                    |                         |
| ⌘ mole     |               |             |             |                    |                         |
| ⌘ second   |               |             |             |                    |                         |

Correct answers:

- 1   meter      2   kilogram      3   second      4   kelvin
- 5   mole

Perform the following conversions.

|           |                       |   |
|-----------|-----------------------|---|
| 16° C     | Convert 61° F to °C   | 1 |
| 292.6 K   | Convert 19.4° C to K  | 2 |
| 1.53 cm   | Convert 15.3 mm to cm | 3 |
| 0.0425 m  | Convert 4.25 cm to m  | 4 |
| 0.2184 kg | Convert 218.4 g to kg | 5 |
| 345.7 K   |                       |   |
| 12° C     |                       |   |
| 2.53 cm   |                       |   |
| 0.425 m   |                       |   |
| 2.184 kg  |                       |   |

Correct answers:

1 16° C 2 292.6 K 3 1.53 cm 4 0.0425 m 5 0.2184 kg

## Exploration

A micrometer is equal to 0.000001 m.

☒ True

☐ False



**The SI system is derived from the \_\_\_\_.**

- ☐ United States system
- ☒ metric system ✓
- ☐ English unit system
- ☐ math system

**Every measuring device measures length to the same degree of accuracy and precision.**

- ☐ True
- ☒ False ✓

**The SI system unit for temperature is \_\_\_\_.**

- ☐ degrees Celsius
- ☐ degrees Fahrenheit
- ☒ kelvin ✓

**One liter is equal to \_\_\_\_.**

- ☐ 1 cm<sup>3</sup>
- ☐ 10 cm<sup>3</sup>
- ☐ 100 cm<sup>3</sup>
- ☒ 1,000 cm<sup>3</sup> ✓

**A meniscus is the curve that forms at the surface of a liquid.**

- ☒ True ✓
- ☐ False

**Graduated cylinders and graduated pipets are designed to measure \_\_\_\_ volume(s).**

- ☒ a range of ✓
- ☐ only one

**Archimedes' method is used to measure the volume of a(n) \_\_\_\_.**

- ☐ square
- ☐ rectangle
- ☒ irregularly shaped object ✓

**Density is derived from SI units of \_\_\_\_\_ and \_\_\_\_\_.**

- ☐ volume; length
- ☐ mass; amount of substance
- ☐ length; mass
- ☒ mass; volume ✓

**In the equation  $C_1 \times V_1 = C_2 \times V_2$ ,  $C_1$  represents the \_\_\_\_ of the solution.**

- ☒ initial concentration ✓
- ☐ initial volume
- ☐ final concentration
- ☐ final volume

**The final digit in any measurement is the estimated, uncertain digit.**

- ☒ True ✓
- ☐ False

## Exercise 1

**Water boils at 100°C at sea level. If the water in this experiment did not boil at 100°C, what could be the reason?**

If the water did not boil at 100°C it is the result of a higher elevation. The higher the elevation (from sea-level) the lower the atmospheric pressure and the lower the boiling point. HOL is located at approximately 5280 feet above sealevel and the boiling point was determined to be 93.8°C.

**While heating two different samples of water at sea level, one boils at 102°C and one boils at 99.2°C. Calculate the percent error for each sample from the theoretical 100.0°C.**

$(102^{\circ}\text{C} - 100^{\circ}\text{C})/100^{\circ}\text{C} * 100 = 2\%$   
 $(99.2^{\circ}\text{C} - 100^{\circ}\text{C})/100^{\circ}\text{C} \times 100 = 0.8\%$

**Data Table 1: Length Measurements**  
 (SAMPLE ANSWER BELOW)

|           | Length (cm) | Length (mm) | Length (m) |
|-----------|-------------|-------------|------------|
| CD or DVD | 12.00       | 120.0       | 0.1200     |
| Key       | 5.23        | 52.3        | 0.0523     |
| Spoon     | 15.00       | 150.0       | 0.1500     |
| Fork      | 20.20       | 202.0       | 0.2020     |

**Data Table 2: Temperature Measurements**  
 (SAMPLE ANSWER BELOW)

|                       | Temperature (°C) | Temperature (°F) | Temperature (K) |
|-----------------------|------------------|------------------|-----------------|
| Hot from Tap          | 35.0             | 95.0             | 308.2           |
| Boiling               | 94.0             | 201.2            | 367.2           |
| Boiling for 5 minutes | 95.5             | 203.9            | 368.7           |
| Cold from Tap         | 19.5             | 67.1             | 292.7           |
| Ice Water - 1 minute  | 5.0              | 41.0             | 278.2           |
| Ice Water - 5 minutes | 4.0              | 39.2             | 277.2           |

**Data Table 3: Mass Measurements**  
 (SAMPLE ANSWER BELOW)

|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
|--|--|--|--|

|                               | Estimated Mass (g) | Actual Mass (g) | Actual Mass (kg) |
|-------------------------------|--------------------|-----------------|------------------|
| Pen or Pencil                 | 3                  | 4.5             | 0.0045           |
| 3 Pennies                     | 10                 | 7.6             | 0.0076           |
| 1 Quarter                     | 5                  | 5.8             | 0.0058           |
| 2 Quarters, 3 Dimes           | 15                 | 18.2            | 0.0182           |
| 4 Dimes, 5 Pennies            | 20                 | 21.6            | 0.0216           |
| 3 Quarters, 1 Dime, 5 Pennies | 35                 | 32.0            | 0.0320           |
| Key                           | 15                 | 12.6            | 0.0126           |
| Key, 1 Quarter, 4 Pennies     | 20                 | 28.2            | 0.0282           |

## Exercise 2

**An unknown, rectangular substance measures 3.60 cm high, 4.21 cm long, and 1.17 cm wide. If the mass is 21.3 g, what is this substance's density (in grams per milliliter)?**

$$\text{Volume} = 3.60 \text{ cm} \times 4.21 \text{ cm} \times 1.17 \text{ cm} = 17.7 \text{ cm}^3$$

$$\text{Mass} = 21.3 \text{ g}$$

$$\text{Density} = 21.3 \text{ g} / 17.7 \text{ cm}^3 \times 1 \text{ cm}^3 / 1 \text{ mL} = 1.20 \text{ g/mL}$$

**A sample of gold (Au) has a mass of 26.15 g. Given that the theoretical density is 19.30 g/mL, what is the volume of the gold sample?**

$$\text{Density} = \text{Mass} / \text{Volume}$$

$$19.30 \text{ g/mL} = 26.15 \text{ g} / x$$

$$19.30 \text{ g} (x) = 26.15 \text{ g (mL)}$$

$$x = 1.355 \text{ mL}$$

A student was given an unknown metal. The student determined that the mass of the metal was 30.2 g. The student placed the metal in a graduated cylinder filled with 20.00 mL of water. The metal increased the volume of water to 22.90 mL. Calculate the density of the metal and determine the identity of the metal using the table below.

| Metal  | Density (g/mL) |
|--------|----------------|
| Lead   | 11.3           |
| Silver | 10.5           |
| Nickel | 9.90           |
| Zinc   | 7.14           |

The calculated density of the unknown metal is 10.4 g/mL. The closest density is 10.5 g/mL, which makes the unknown silver.

Data Table 4: Liquid Measurements  
(SAMPLE ANSWER BELOW)

|                                            | Water | Isopropyl Alcohol |
|--------------------------------------------|-------|-------------------|
| Mass A: Graduated Cylinder (g)             | 19.9  | 19.9              |
| Volume (mL)                                | 5.0   | 5.0               |
| Mass B: Graduated Cylinder with Liquid (g) | 24.7  | 23.7              |
| Mass B-A: Liquid (g)                       | 4.8   | 3.8               |
| Density (g/mL)                             | 0.97  | 0.76              |
| Percent Error (%)                          | 3.5   | 3.3               |

Data Table 5: Magnet - Direct Measurement Method  
(SAMPLE ANSWER BELOW)

|             | Magnet |
|-------------|--------|
| Mass (g)    | 4.3    |
| Length (cm) | 2.56   |
| Width (cm)  | 0.59   |
| Height (cm) | 0.59   |



|                              |      |
|------------------------------|------|
| Volume (cm <sup>3</sup> )    | 0.89 |
| Density (g/cm <sup>3</sup> ) | 4.8  |

Data Table 6: Water Displacement Method  
(SAMPLE ANSWER BELOW)

|                                           | Magnet | Metal Bolt |
|-------------------------------------------|--------|------------|
| Mass (g)                                  | 4.3    | 8.0        |
| Initial Volume of Graduated Cylinder (mL) | 7.1    | 6.5        |
| Final Volume of Graduated Cylinder (mL)   | 8.0    | 7.5        |
| Object Volume (mL)                        | 0.9    | 1.0        |
| Density (g/mL)                            | 5      | 8.0        |

### Exercise 3

**How would you prepare 10.0 mL of a 0.25% *m/v* HCl solution if 1% *m/v* HCl was available? How much 1% *m/v* HCl is needed? How much distilled water is used?**

$$C_1 \times V_1 = C_2 \times V_2$$

$$(1\%) \times (x \text{ mL}) = (0.25\%) \times (10.0 \text{ mL})$$

$$X = 2.5 \text{ mL}$$

Thus, 2.5 mL of 1% HCl is needed and it is combined with 7.5 mL of distilled water to create the total volume of 10 mL of 0.25% HCl.

The 0.25% solution would then be prepared by adding 7.5 mL of distilled water to a flask and adding the 2.5 mL of the 1% HCl drop wise to the distilled water to reach a total volume of 10.0 mL.

**From the graph of Density vs. Concentration, created in Graph 1, what was the relationship between the concentration of the sugar solution and the density of the sugar solution?**

From the graph of Density vs. Concentration, as the concentration of the sugar solution increases the density does as well. Likewise, as the concentration of the sugar solution decreases, the density of the solution decreases to the point of 1.006 g/mL. The density of the sugar solution will not drop below the density of the water.

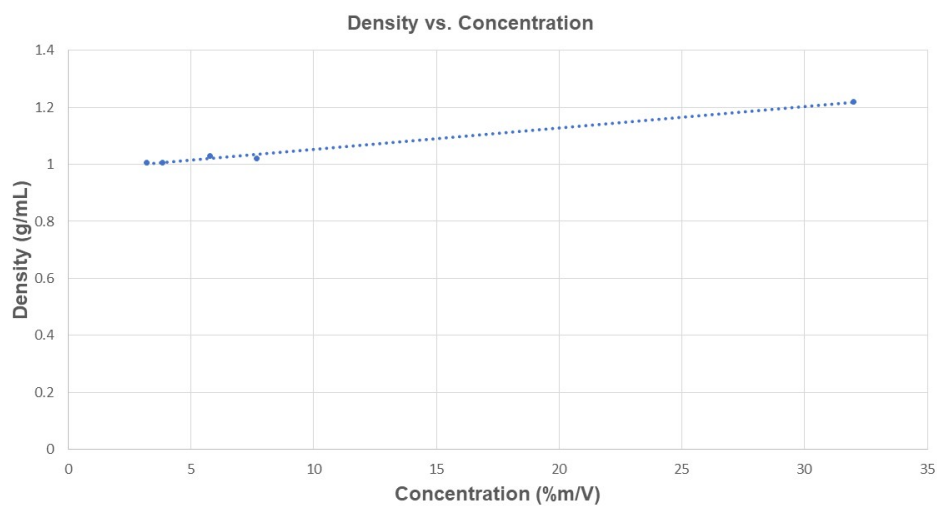
**Data Table 7: Initial Concentration**  
(SAMPLE ANSWER BELOW)

|                               |                                                          |
|-------------------------------|----------------------------------------------------------|
|                               | Sugar (C <sub>12</sub> H <sub>22</sub> O <sub>11</sub> ) |
| Mass of Volumetric Flask (g)  | 26.4                                                     |
| Mass of Sugar (g)             | 8.0                                                      |
| Total Volume (mL)             | 25.00                                                    |
| Concentration (% <i>m/V</i> ) | 32                                                       |

**Data Table 8: Solutions**  
(SAMPLE ANSWER BELOW)

| Solution | Volume (mL) | Mass (g) | Density (g/mL) | Initial Concentration (% <i>m/v</i> ) | Volume Transferred (mL) | Final Concentration (% <i>m/v</i> ) |
|----------|-------------|----------|----------------|---------------------------------------|-------------------------|-------------------------------------|
| 0        | 25.00 mL    | 27.9     | 1.11           |                                       | 0.0                     | 32                                  |
| 1        | 25.00 mL    | 25.2     | 1.006          | 32                                    | 2.5                     | 3.2                                 |
| 2        | 25.00 mL    | 25.4     | 1.03           | 32                                    | 4.5                     | 5.8                                 |
| 3        | 25.00 mL    | 25.2     | 1.006          | 32                                    | 3.0                     | 3.8                                 |
| 4        | 25.00 mL    | 25.5     | 1.02           | 32                                    | 6.0                     | 7.7                                 |

**Graph 1: Density versus Concentration**  
(SAMPLE ANSWER BELOW)



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## Competency Review

**The SI system unit for the amount of a substance is \_\_\_\_.**

- ☐ grams per liter
- ☒ moles
- ☐ Avogadro's number
- ☐ kilograms



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**The International System of Units (SI) is \_\_\_\_.**

- ☐ a scale of measurement
- ☐ the same as U.S. Customary Units
- ☐ the same as English units
- ☒ a standard system to measure length, temperature, time, amount of substance, and mass



**Convert 15.00°F to °C.**

- ☐ 1.58°C
- ☐ 8.33°C
- ☒ -9.40°C ✓
- ☐ 59°C
- ☐ -8.7°C

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**Convert 5.00 miles to kilometers.**

- ☒ 8.05 km ✓
- ☐ 3.11 km
- ☐ 2.49 km
- ☐ 1.53 km

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**A meniscus is the curve that forms at the surface of a liquid.**

- ☒ True ✓
- ☐ False

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**\_\_\_\_\_ is defined as mass per unit of measure.**

- ☐ Volume
- ☐ A kilogram
- ☐ Molarity
- ☒ Density ✓
- ☐ Concentration

The definition of %  $m/V$  is \_\_\_\_.

- ☒ grams solute/mL solution x 100 ✓
- ☐ grams solution/mL solute x 100
- ☐ mL solute/grams solution x 100
- ☐ mL solution/grams solute x 100

Significant figures include only the certain digits of a measurement.

- ☐ True
- ☒ False ✓

When reading a graduated cylinder made of glass, one must read the volume at eye level from the middle of the meniscus.

- ☐ True
- ☒ False ✓

A volumetric flask contains 25.0 mL of a 14%  $m/V$  sugar solution. If 2.5 mL of this solution is added to 22.5 mL of distilled water, what is the %  $m/V$  of the new solution.

- ☒ 1.4 %  $m/V$  ✓
- ☐ 14 %  $m/V$
- ☐ 7.1 %  $m/V$
- ☐ 71 %  $m/V$

Calculate experimental error using the following data: the measured value equals 1.4 cm; the accepted value equals 1.2 cm.

- ☐ -14.3%
- ☐ 14.3%
- ☐ -16.7%
- ☒ 16.7% ✓

What is the volume of an irregularly shaped object that has a mass 3.0 grams and a density of 6.0 g/mL?

- ☐ 1.0 mL
- ☒ 0.5 mL
- ☐ 2.0 mL
- ☐ 18.0 mL



## Extension Questions

In the movie, "*Raiders of the Lost Ark*", Indiana Jones takes a gold idol from a cave. The statue is resting on a table which is rigged with a weight sensor. The weight sensor can detect when the weight is removed and will set off a series of unfortunate accidents. To prevent this from happening, Indiana replaces the gold idol with a bag of sand. The volume of the gold idol is approximately 1.0 L. The density of gold is 19.3 g/mL and the density of sand is 2.3 g/mL.

- a. Assuming the idol is pure gold, what volume would the bag of sand have to be in order to weigh exactly the same as the idol and not set off the booby-traps?
- b. Let's assume that Indiana is successful in removing the idol and returning with it to his laboratory. He decides to determine if it is really pure gold. He weighs the idol and measures the volume by a water displacement method. The results are: mass = 16.5 kg and volume of water displaced = 954 mL. Is the idol made of pure gold? Explain your answer based on the experimental results.

(SAMPLE ANSWER BELOW)

Mass of idol = 1.0 L x (1000 mL/L) x (19.3 g/mL) = 19,300 g The mass of sand must equal the mass of the idol = 19,300 g The volume of sand can be calculated from: volume = mass/density Volume of sand = 19,300 g/(2.3 g/mL) = 8.390 L, which is an unrealistic volume for Indiana Jones to handle with one hand.

The density of the idol from the testing would be calculated as [16.5 kg x (1000 g/kg)]/954 mL = 17.3 g/mL No, the idol is not pure gold. The density is too low.

In the movie, "*Raiders of the Lost Ark*", Indiana Jones takes a gold idol from a cave. The statue is resting on a table which is rigged with a weight sensor. The weight sensor can detect when the weight is removed and will set off a series of unfortunate accidents. To prevent this from happening, Indiana replaces the gold idol with a bag of sand. The volume of the gold idol is approximately 2 L. The density of gold is 19.3 g/mL and the density of sand is 2.3 g/mL.

- a. Assuming the idol is pure gold, what volume (in L) would the bag of sand have to be in order to weigh exactly the same as the idol and not set off the booby-traps? Show your work. Is this a feasible sand bag to carry? Why or why not?

- b. Let's assume that Indiana is successful in removing the idol and returning with it to his laboratory. He decides to determine if it is really pure gold. He weighs the idol and measures the volume by a water displacement method. The results are: mass = 12.4 kg and volume of water displaced = 752 mL. Is the idol made of pure gold? Show your work, and explain your answer based on the experimental results.

(SAMPLE ANSWER BELOW)

- a. The volume of the sand bag would have to be 16.8 L. This is way too large of a bag to feasibly carry around (it's about 4.5 gallons).

**b. The idol is not made of pure gold.  $12400\text{g}/752\text{mL} = 16.5\text{ g/cm}^3$ . Gold's density is  $19.3\text{ g/cm}^3$ .**