T U R B I D I T Y

What is Turbidity?

- A measure of relative water clarity
- A measure of suspended solids
- An indicator of water quality

What is Turbidity?

- Suspended particles may include
  - Silt
  - Clay
  - Algae and Other Microorganisms
  - Organic Matter
  - Other Minute Particles

What is Turbidity?

- Solids in Water:
  - Support growth of harmful microorganisms
  - Reduce effectiveness of chemical disinfection
  - Interfere with chemical and biological analysis
  - Have poor aesthetics
  - Are unacceptable for most industrial applications

What is Not Turbidity?

- Turbidity is NOT:
  - A direct measure of total suspended solids (TSS) concentration
  - Able to identify the type of particles
  - A spectrophotometric analysis

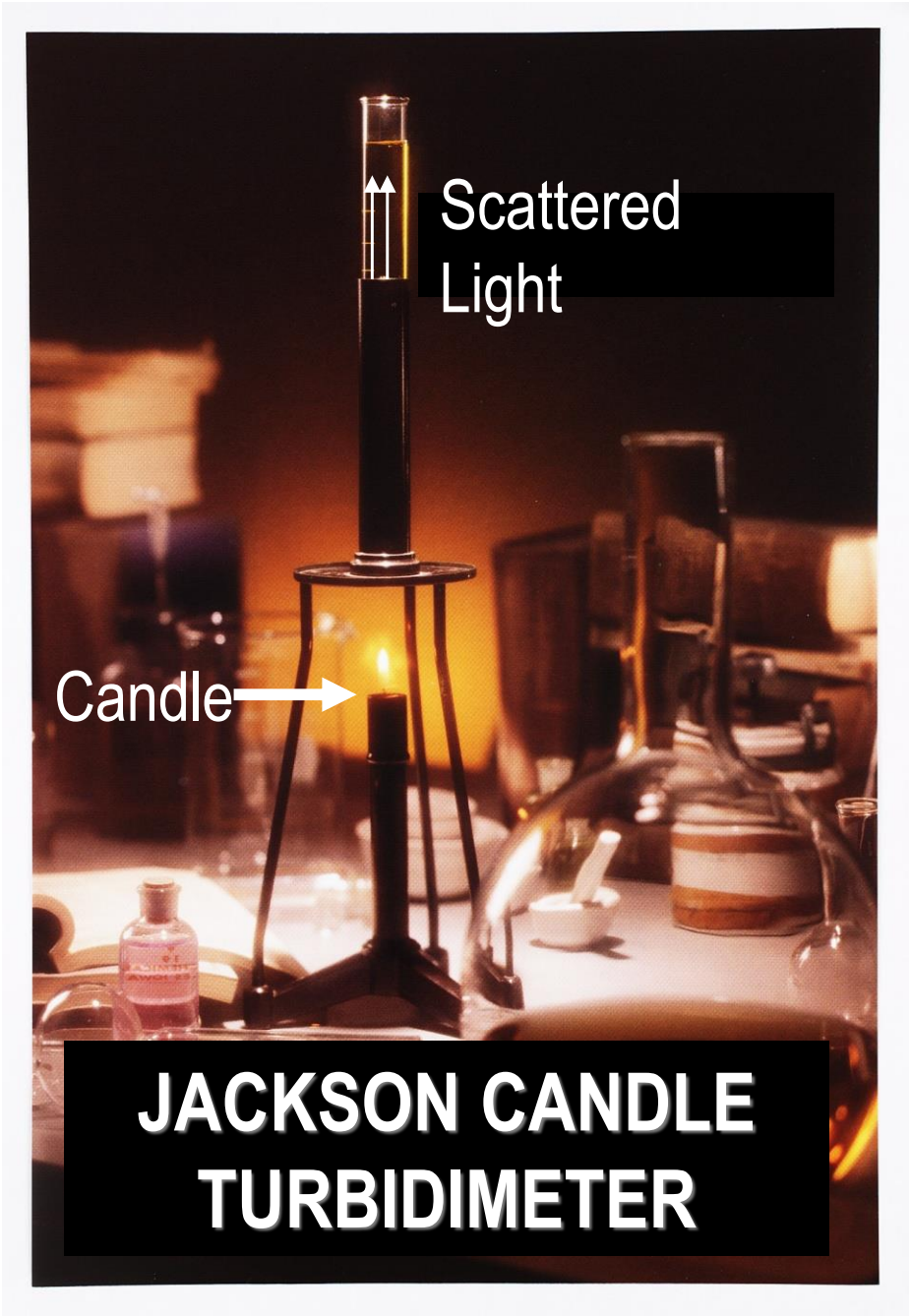
Drinking Water

- Requires low turbidity
- Solids in drinking water
  - Reduce effectiveness of disinfection
  - May support microorganisms
  - Poor aesthetics

Turbidity Instrumentation

Measurement Strategies

- Historical progression of turbidity measurement
  - Jackson Candle - visual extinction
  - Photometer - light transmission
  - Nephelometry - 90^{o} light scatter


Scattered
Light
Candle
JACKSON CANDLE
TURBIDIMETER

Photometers

- Once photometers were developed, light transmission was used to measure turbidity.

Photometer Problems

- Low turbidity (drinking water levels)
  - Transmittance changes too small to measure
- High turbidity
  - Light scattering by many particles interferes with light absorption

Nephelometers

- Use a 90° design in their optical system
  - Detector 90^{o} from light source
- Results are reported as Nephelometric Turbidity Units (NTU).
- Required for EPA reporting

How do Nephelometers Work?

- Measure the amount of light scattered by a sample

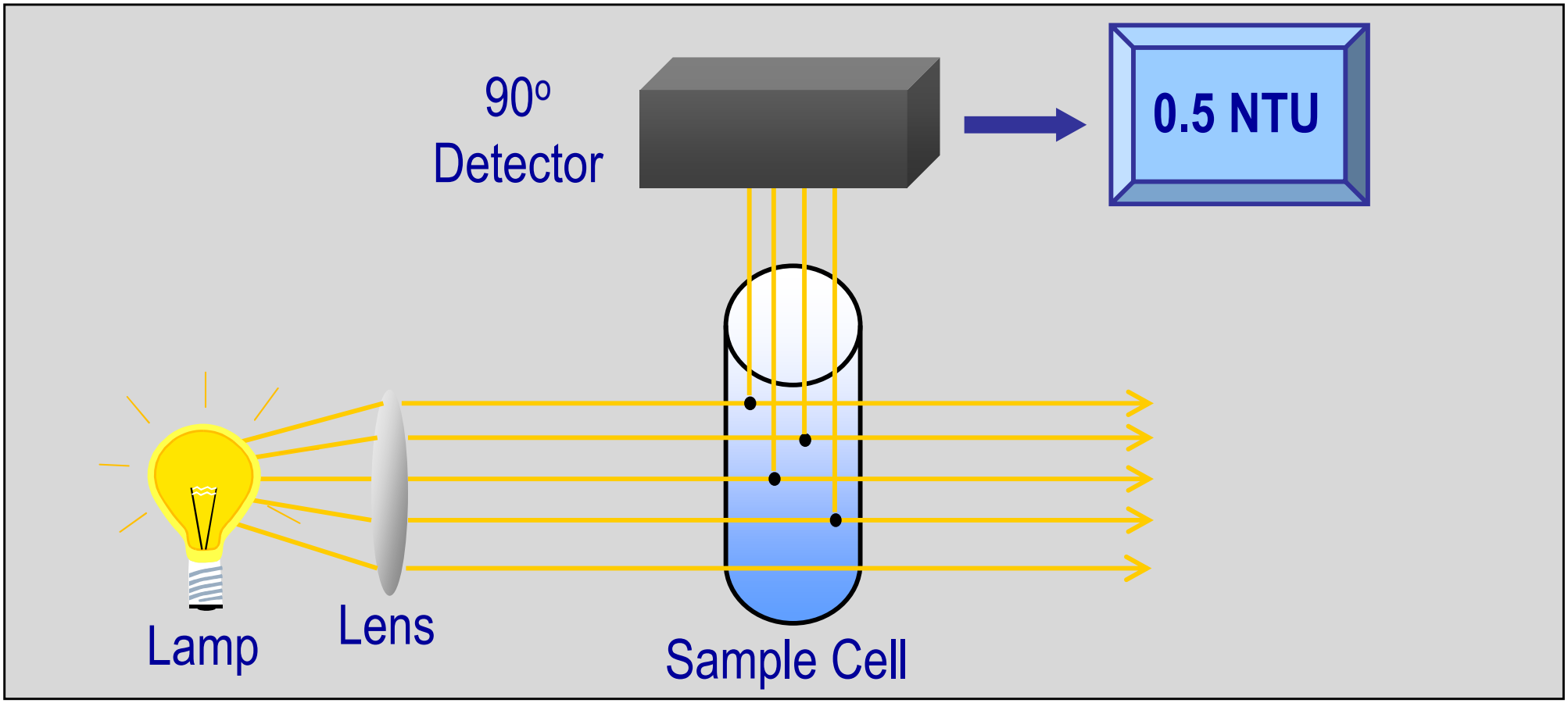
Photometer

Transmitted light

Nephelometer

Scattered light

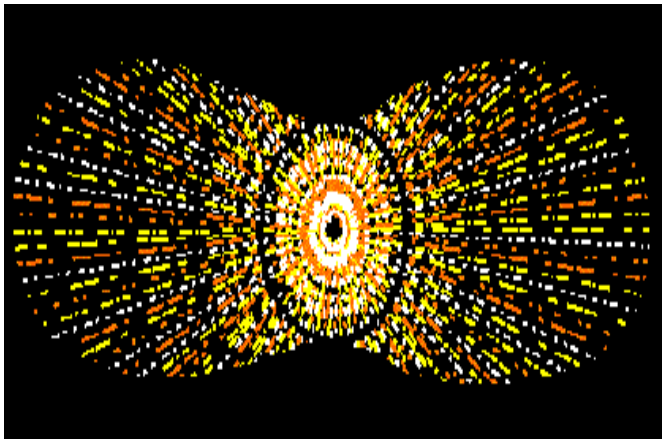
Basic 90° Nephelometer



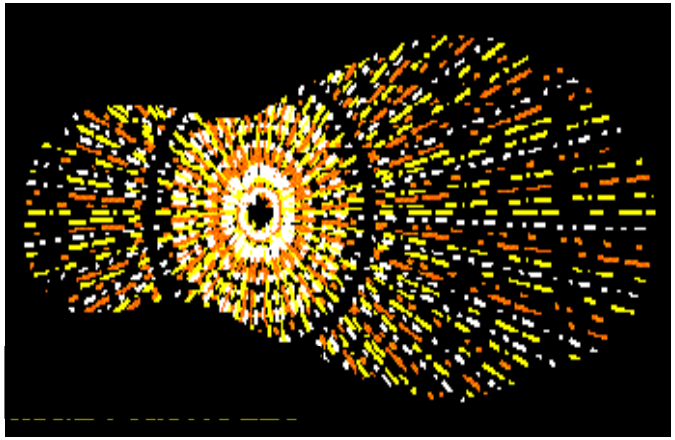
Why 90 Degrees?

- Many factors affect light scattering:
  - Particle Size
  - Particle Shape
  - Refractive Index
  - Color of Particles and Fluid
  - Particle Concentration
- Nephelometers attempt to minimize the effects of these factors while maximizing measurement accuracy.

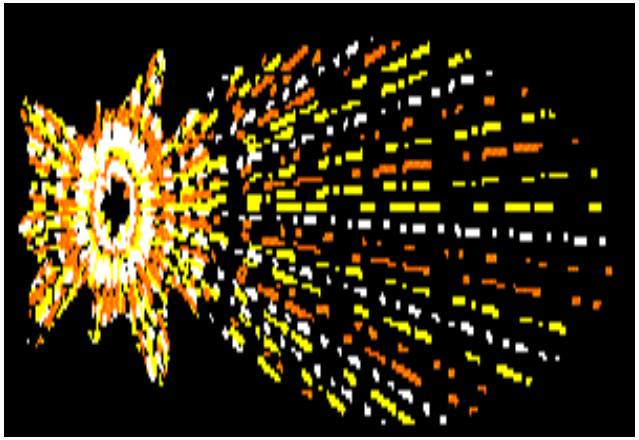
Why 90 Degrees?



Small Particles



Larger Particles

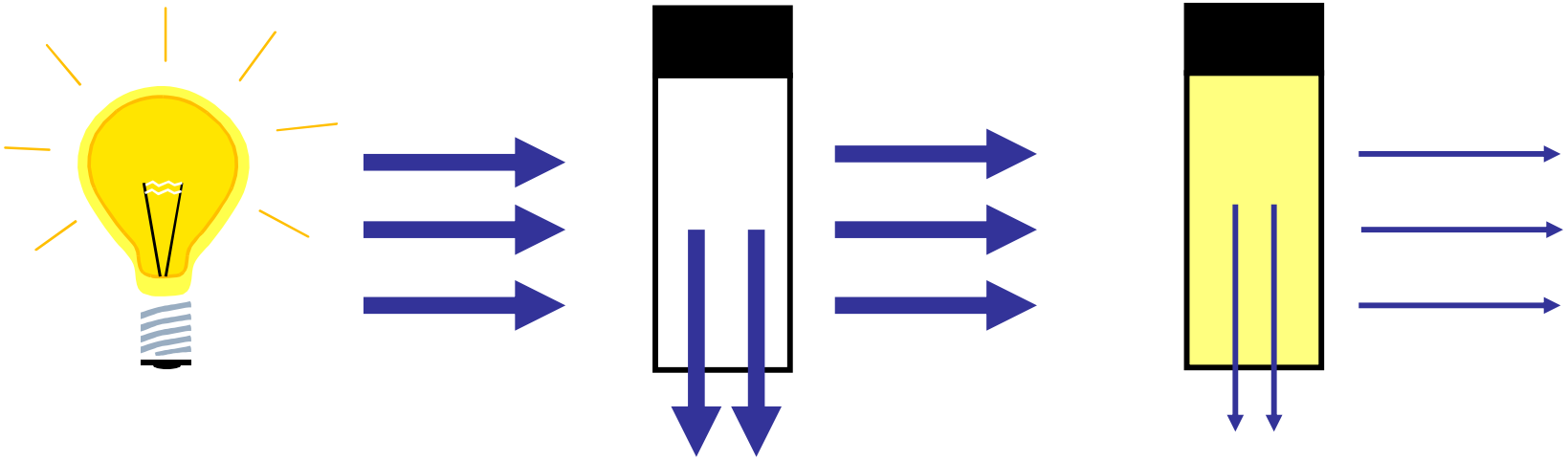


Even Larger Particles

Measure light scattering at 90 degrees to minimize the effect of particle size

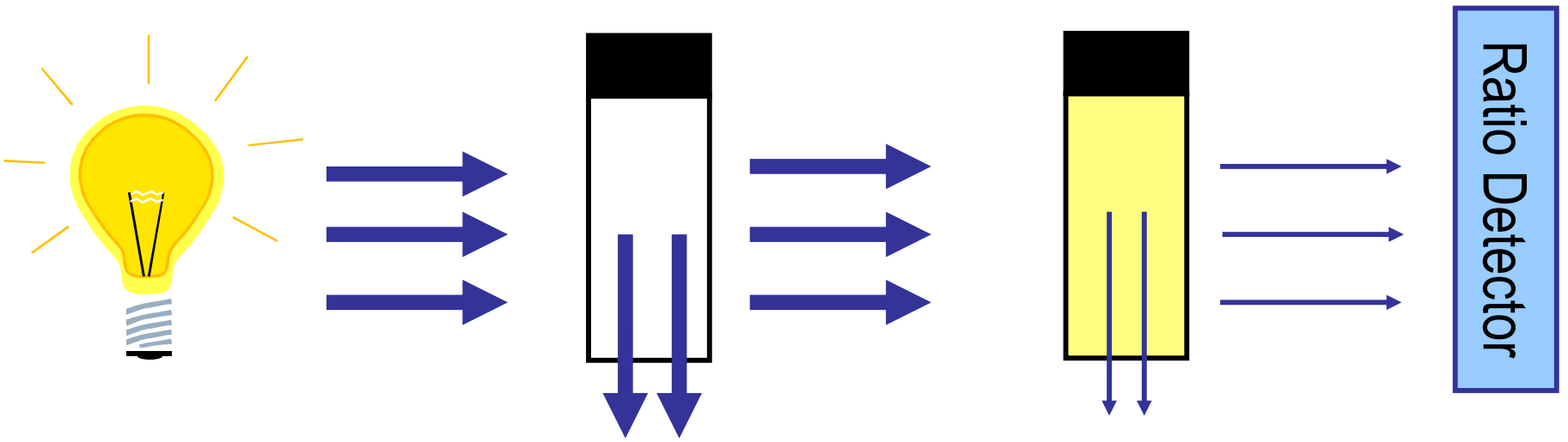
Color of Particles and Solution

- Colored substances absorb light.
- If light is absorbed, then less light reaches the detector and the measured turbidity will be lower.

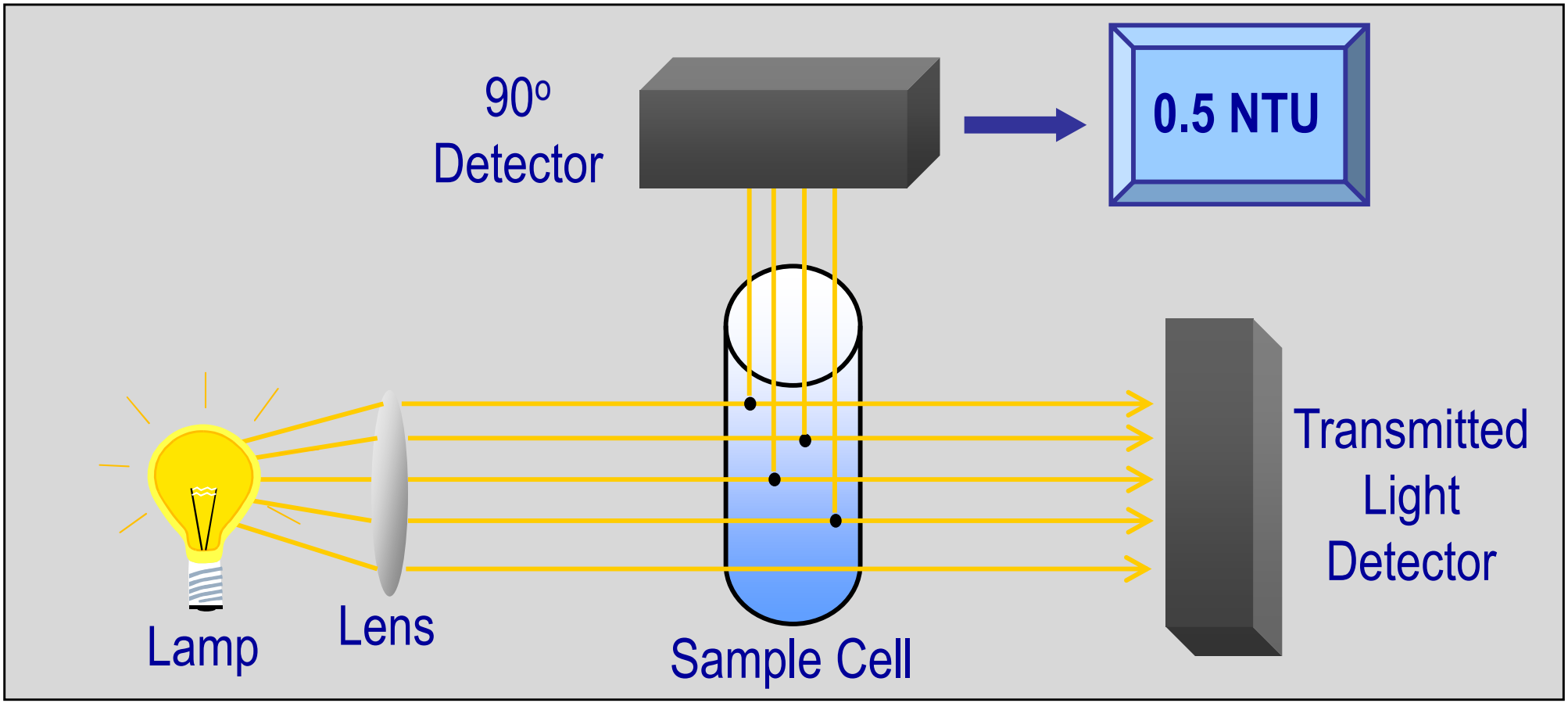


Color of Particles and Solution

- Correct for this with a ratio nephelometer.
- Additional detector measures amount of light absorbed by sample and performs correction.

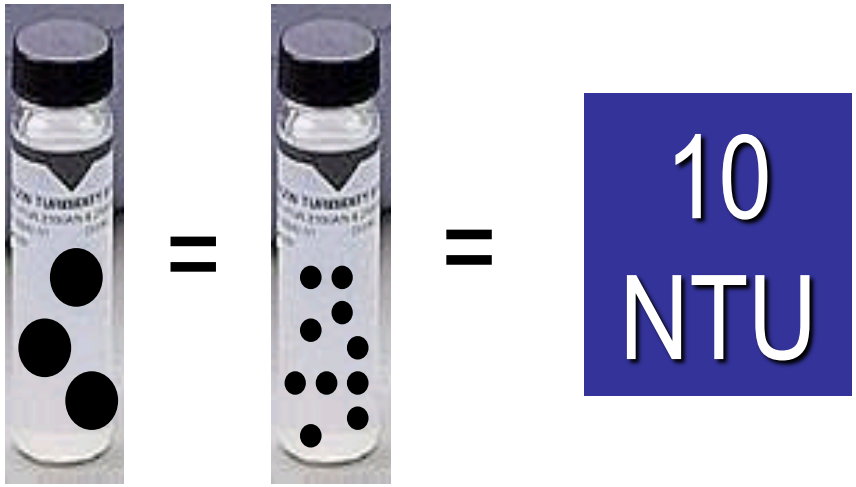


Ratio Nephelometer



Particle Concentration

- A few large particles may scatter as much light as many small ones.
  - A direct comparison from NTU to mg/L solids may not always be possible



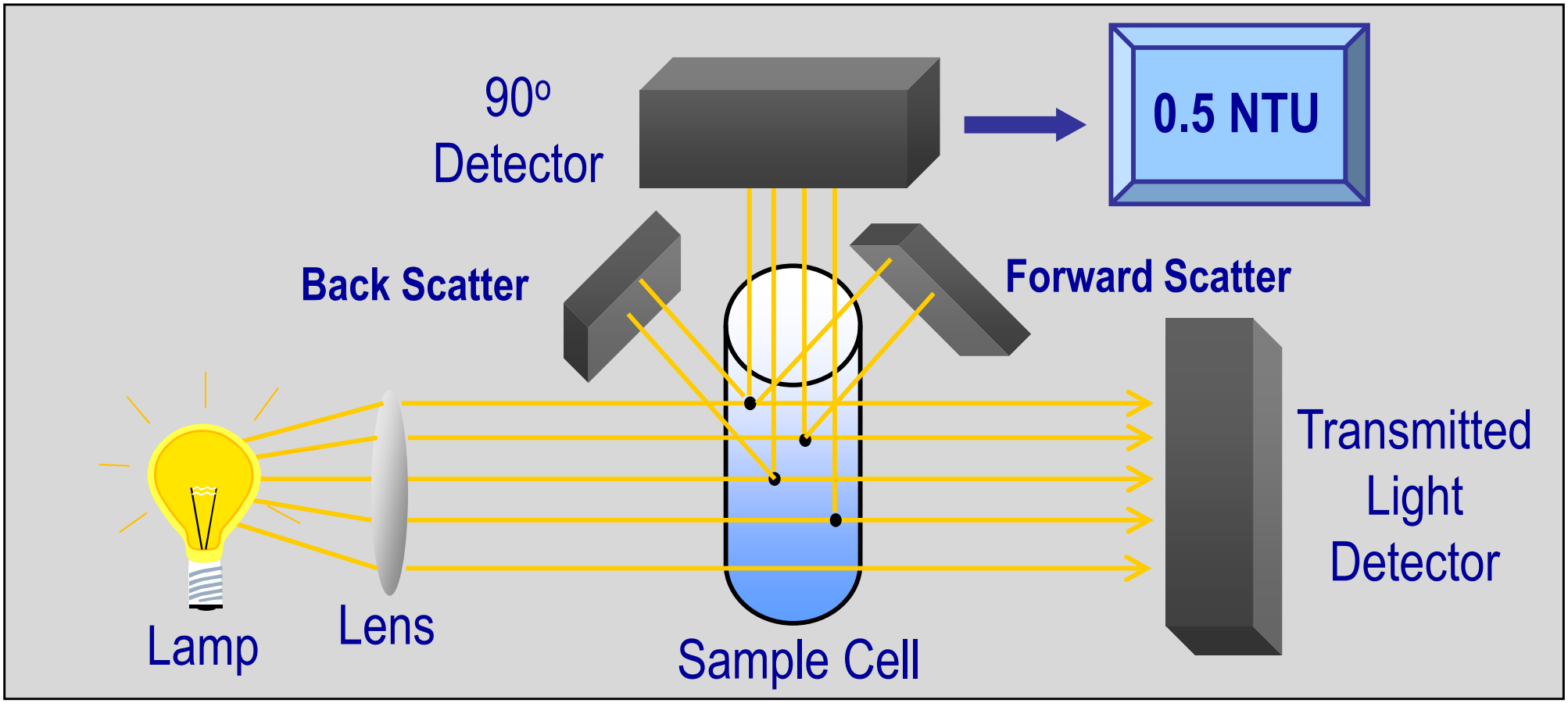
Particle Concentration

- Extremely high particle concentrations can cause the same light to be scattered by large particles.
  - It may reach the point where accurate measurement
    is impossible.

Nephelometers - Stability and Range

- Additional detectors increase the range of measurements and add stability
  - Forward scatter
  - Back scatter

Additional Detectors



Nephelometers - USEPA Requirements

- Tungsten-halogen lamp operated at a filament color temperature of 2200-3000K
- Light path through sample ≤ 10cm
- Scattered light detected at 90 ± 30^{o}
- Detector and filter system response peaks between 400-600nm

Turbidity Measurement

Measuring Turbidity

- Turbidity is just plain different than colorimetry
  - No zero (impossible to measure zero turbidity)
  - Not a comparison measurement
  - Requires calibration on a regular basis

Measuring Turbidity

- In *theory*, relatively simple to understand
- In *practice*, an accurate measurement is not so simple - especially <1.0 NTU
  - Recognize potential error sources
  - Techniques to minimize error

Sources of Error

- Stray Light - Excess light in the system (from any source) contributing to a high turbidity measurement
  - Sample Cells
  - Gas Bubbles
- Improper Calibration

Sample Cells

- Contaminated cells
  - Dirty sample cells can give a false positive reading
- Scratched cells
  - Scratched cells may scatter light and give a false positive reading

Sample Cells - How to Improve

- Contaminated cells
  - Cells must be meticulously clean
    - Wash with detergent, acid
    - Ultrasonic bath
    - Rinse with filtered deionized water

Sample Cells - How to Improve

- Make the cell as *invisible* as possible
- Scratched cells
  - Hide or minimize effects of scratches
    - Silicone oil to mask scratches
    - Index sample cells

Gas Bubbles - How to Improve

- Bubbles scatter light and will give a high reading
- Degas Sample
  - Time - let sample sit for a few minutes
  - Ultrasonic bath
  - Draw vacuum

Stray Light - How to Improve

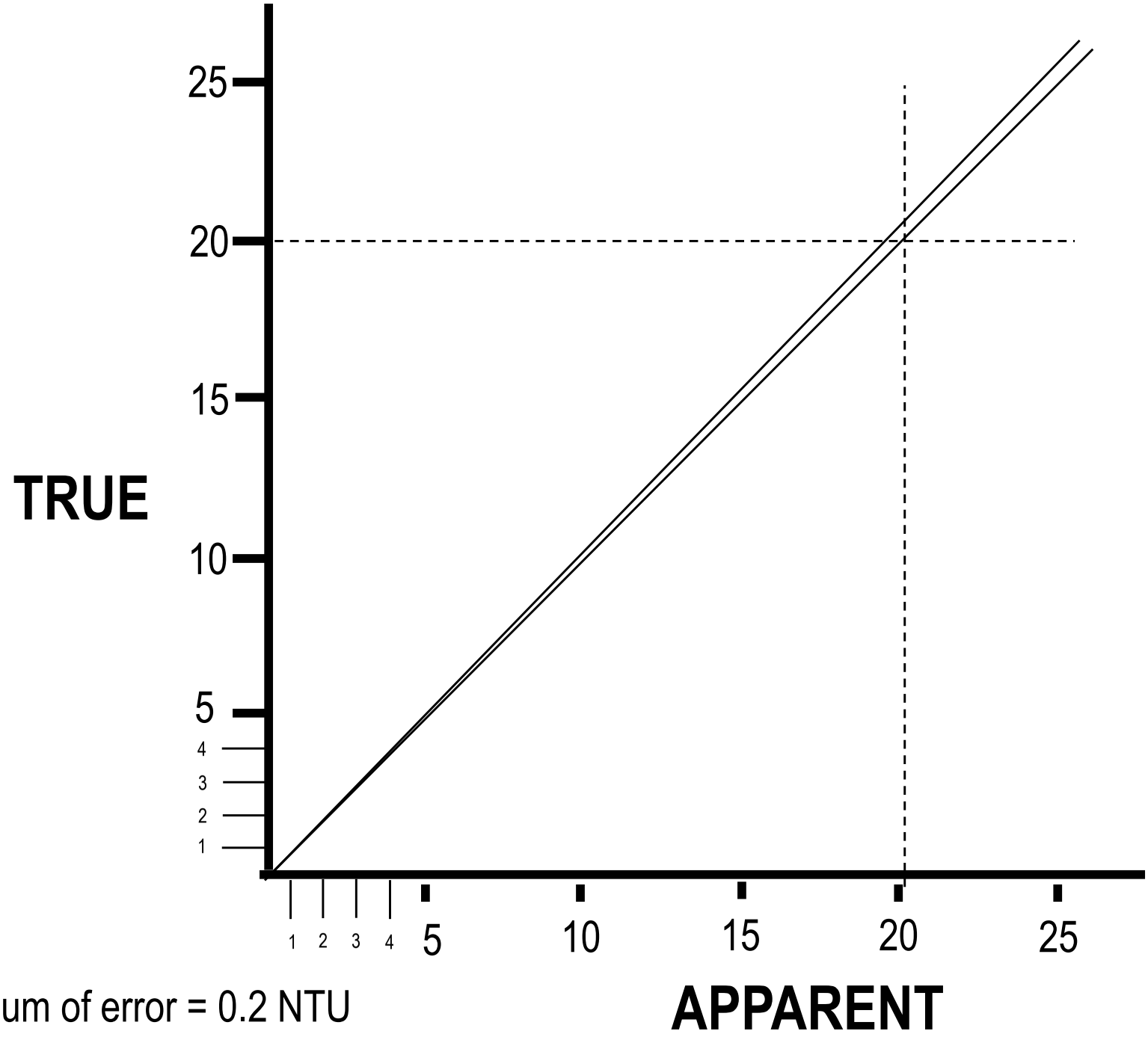
- Stray light allows more light to reach detector = false high turbidity reading
  - Keep sample compartment and optics clean

Calibration - How to Improve

- Improper calibration can lead to inaccurate measurements
  - Calibrate regularly with primary standards at the values recommended by the manufacturer
  - Hach recommends standards no less than 20 NTU - *even if measurements are <1.0 NTU*

Calibration
Why Calibrate at 20NTU?

- Typical error in standard preparation estimated at about 0.23NTU
  - Small amounts of error (0.23) in a 20NTU standard will not affect accuracy of low level measurements
  - The same amount of error (0.23) in a 0.5NTU standard will greatly affect accuracy of low level measurements



Sum of error = 0.2 NTU

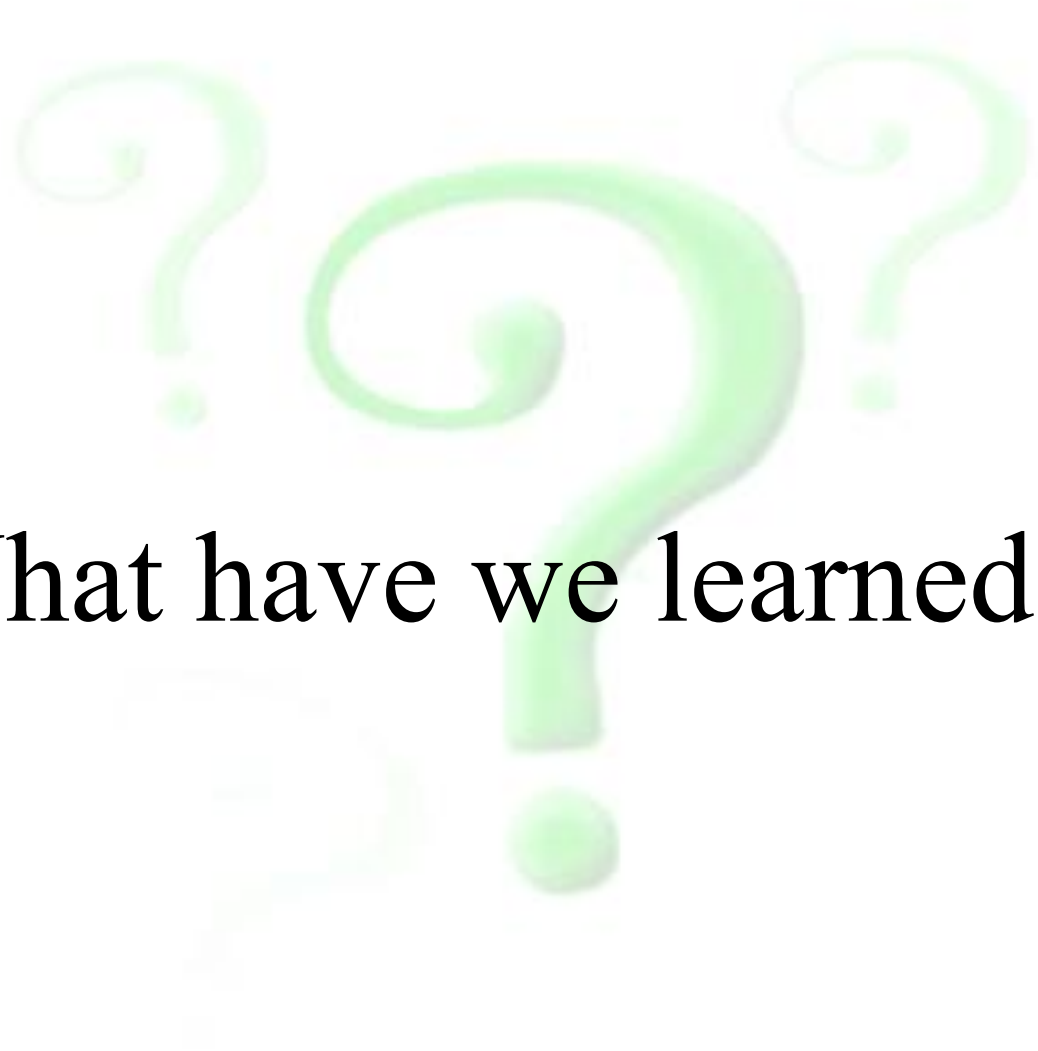
Hach's Calibration Recommendations

- Do not prepare a low concentration standard for calibration
- Calibrate with recommended standards (20NTU) and verify calibration with certified low-level StablCal standards.
  - Certified 0.3, 0.5, and 1.0NTU StablCal standards

Turbidity Measurements

- Clean sample cells
- Use silicone oil
- Degas sample
- Maintain instrument
- Follow proper calibration procedure

T U R B I D I T Y



What have we learned?

Turbidity measures the amount of _____ a sample scatters

light

Turbidity is not a direct measure of _____ _____ concentration

suspended solids

Turbidity is measured with a _____, and uses a _____ degree light scatter

nephelometer, 90

Nephelometers use a 90 degree scatter technique to minimize the effects of varying particle ____

size

A ratio turbidimeter compensates for absorbance loss caused by sample _____

color

Turbidimeters should be _____ quarterly, and can be _____using secondary standards daily

calibrated, verified

For an accurate turbidity reading, it is critical that sample cells be ____ and free of _____

clean, scratches

Silicon _____ is used to reduce the affects of scratches on sample cells

oil

Thank You

Ted Simmons
Hach Company
800-227-4224 x2113
tsimmons@hach.com