Strong Acid vs. Strong Base Titration

Schweitzer

Strong Acid vs. Strong Base

- HCl vs. NaOH
  - $HCl + NaOH \rightarrow NaCl + H_2O$

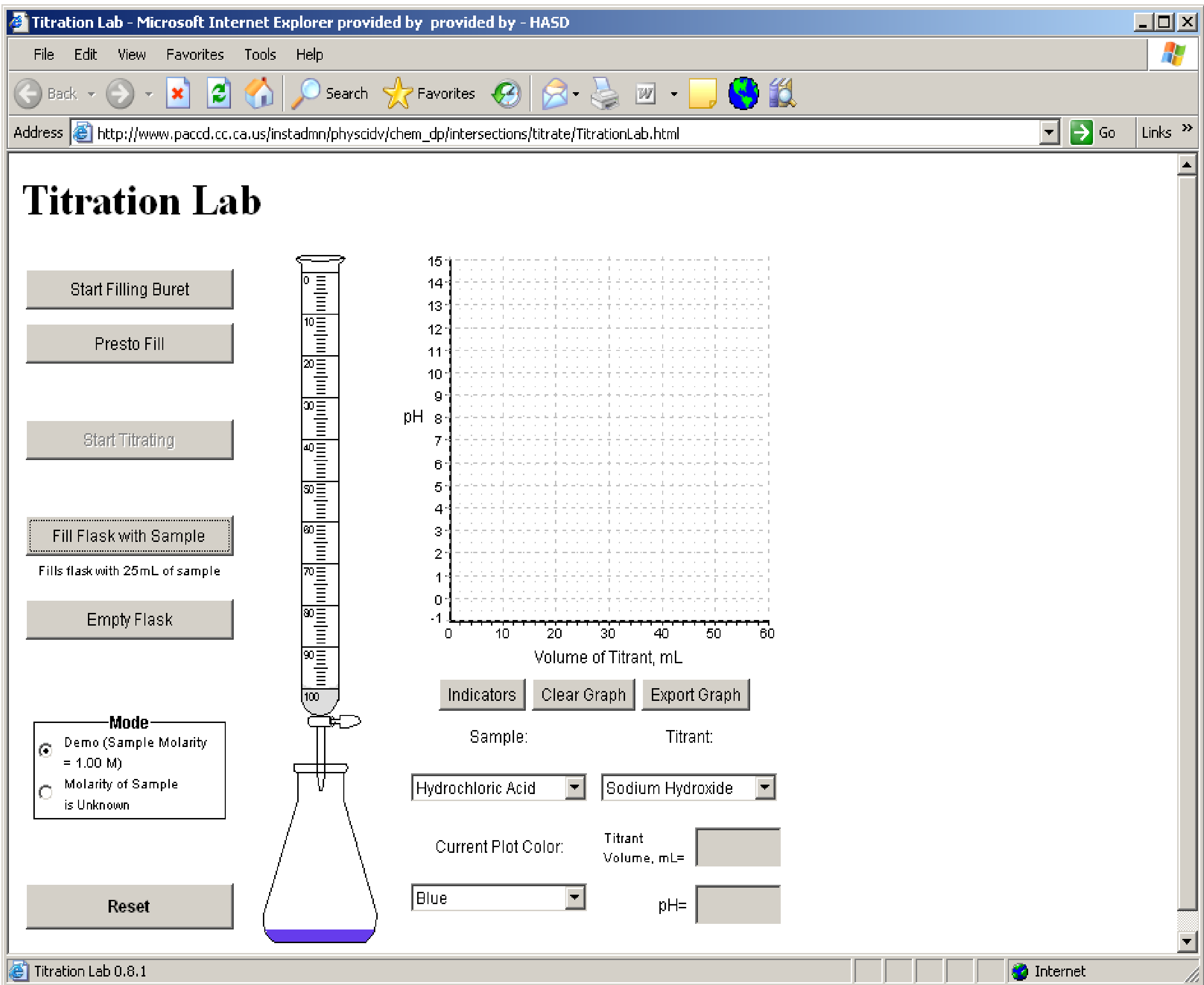
- HCl = Strong Acid
- NaOH = Strong Base
- NaCl = Neutral Salt
- H_2O = neutral

Terms

- Equivalence point: When you have added an equal number of moles of acid and base.

- Neutralization point: When you have added enough solution to make the mixture neutral.

HCl vs. NaOH



Buret: NaOH

- 1.0 M
- Zero added

Flask:

- HCl
- 1.0M
- 25 mL

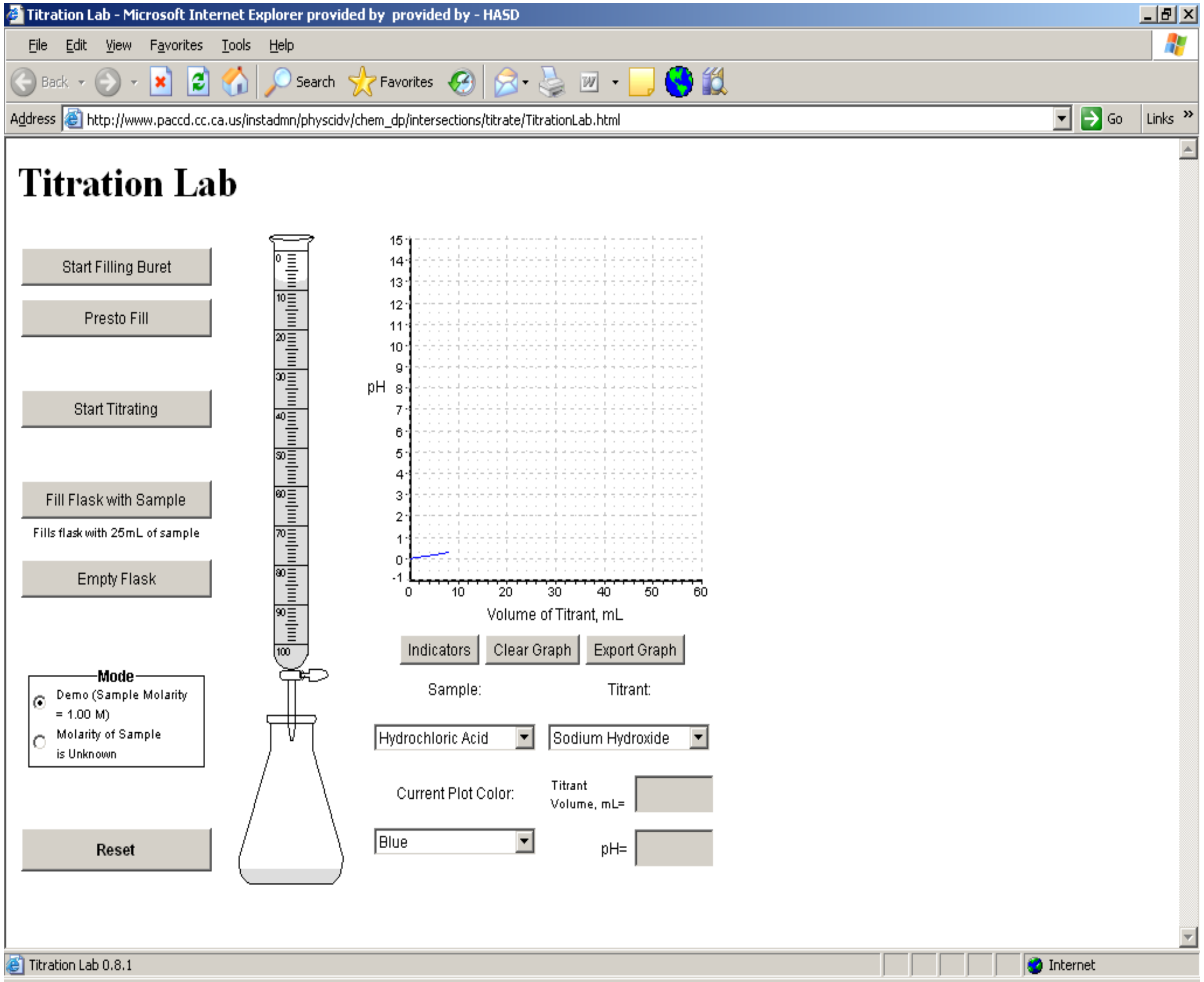
Moles of HCl

- .025 moles

HCl vs. NaOH

- What will be our equivalency point?
- HCl 1.0M
- 25mL
  - Vs.
- 1.0M NaOH
- ?
  - When 25 mL of NaOH is added we will have added equivalent moles.

HCl vs. NaOH



Buret: NaOH

1.0 M

10ml added

Moles of HCl

- .025 moles

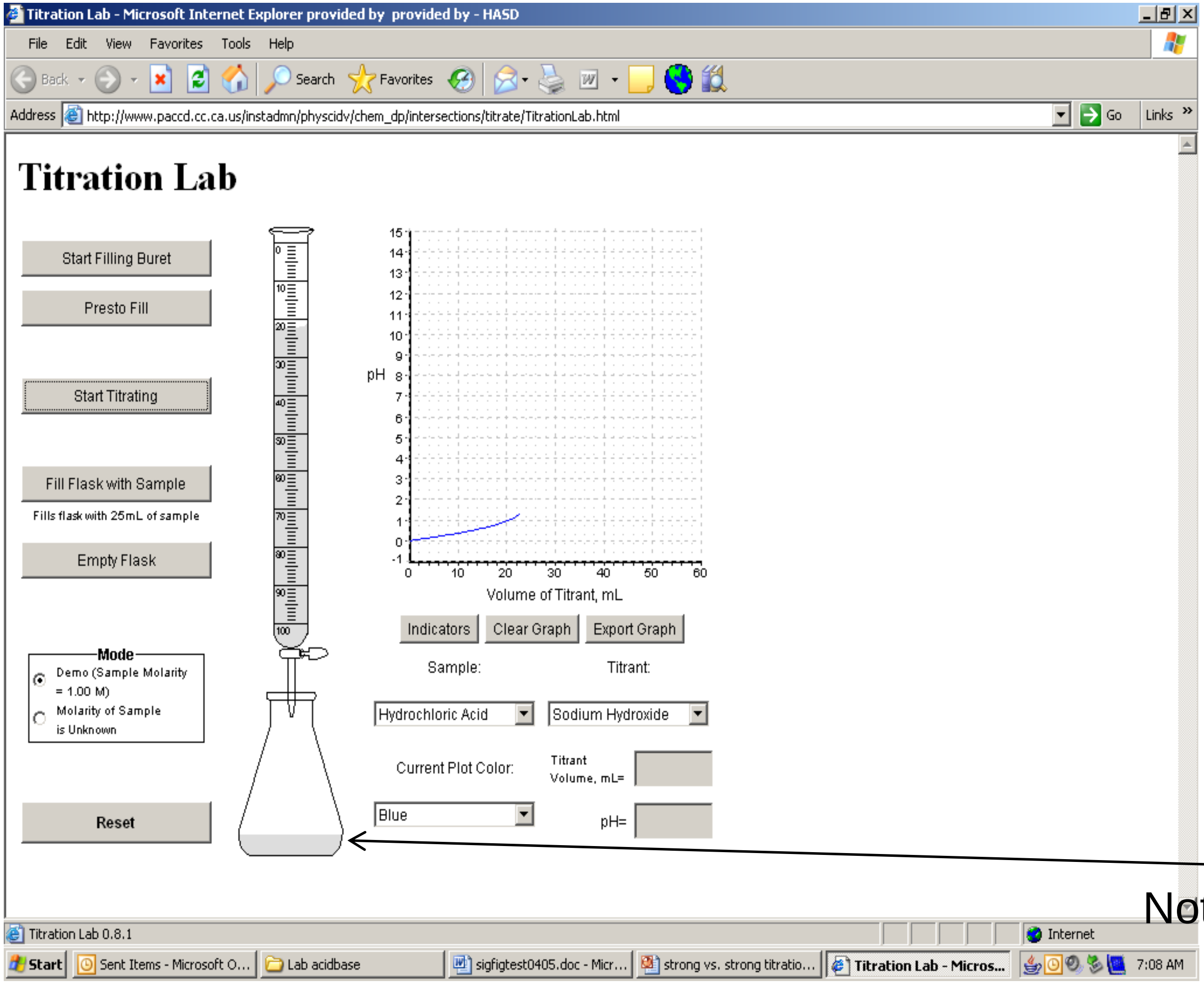
- Indicator:

- Phenolphthalein

- Notice the pH is acidic

- Solution is colorless

HCl vs. NaOH



Buret: NaOH

1.0 M

22ml Added

Moles of HCl

- .025 moles

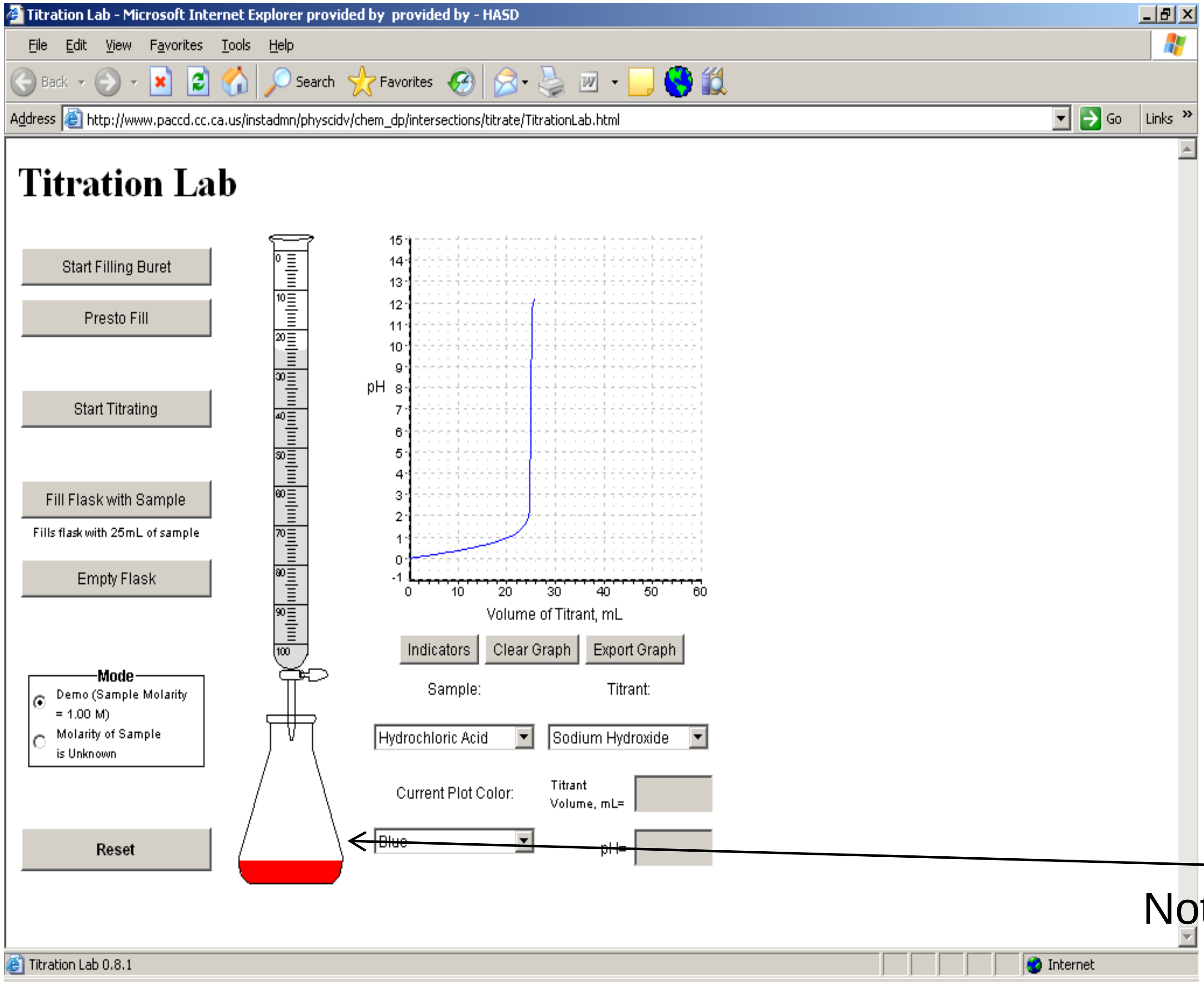
- Indicator:

- Phenolphthalein

- Why is the pH increasing

Note: Indicator is Clear

HCl vs. NaOH



Buret: NaOH

1.0 M

26ml Added

Moles of HCl

- .025 moles

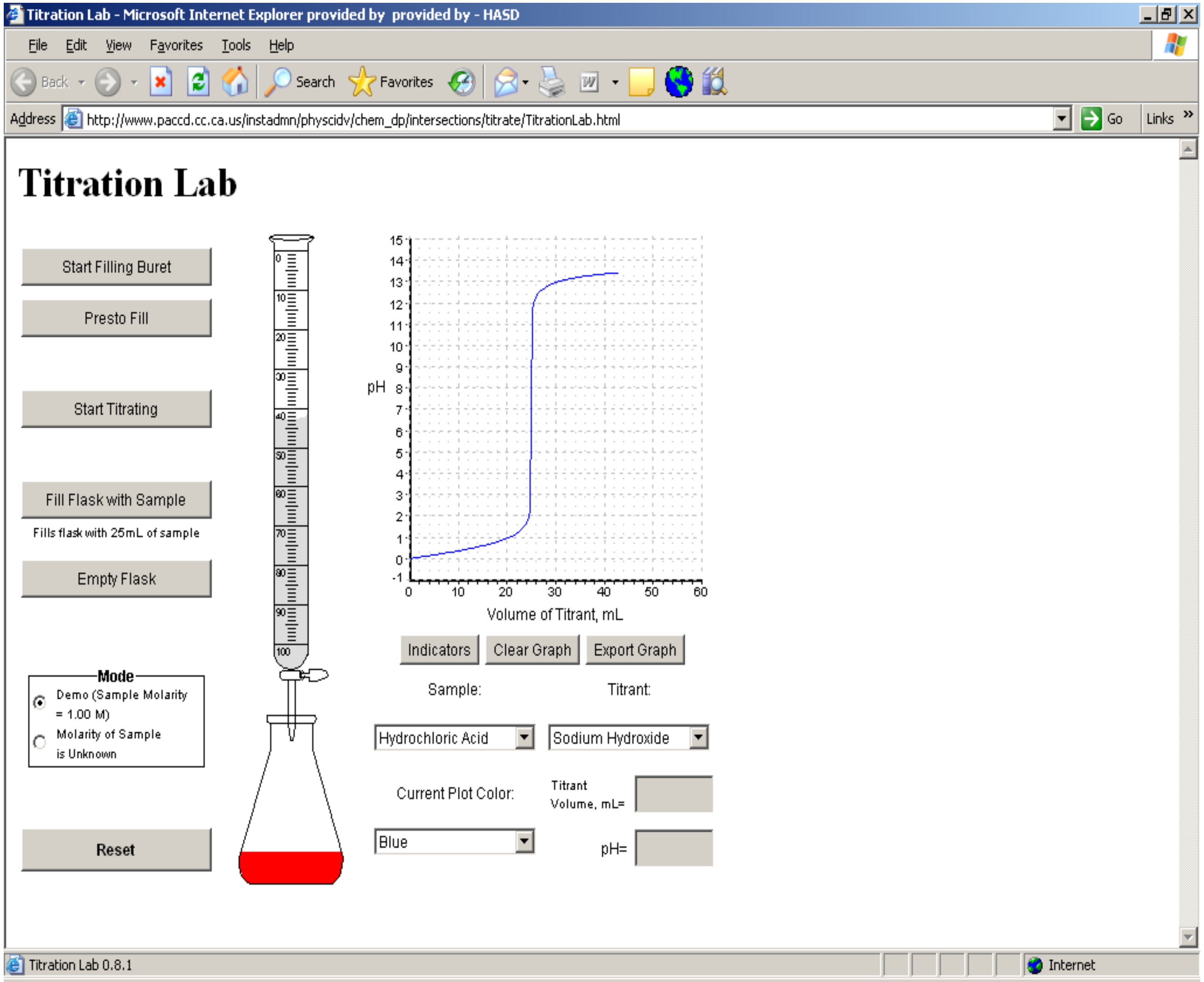
- Indicator:

- Phenolphthalein is red

- What happed?

Note: Indicator is pink

HCl vs. NaOH



Buret: NaOH

1.0 M

42ml Added

Moles of HCl

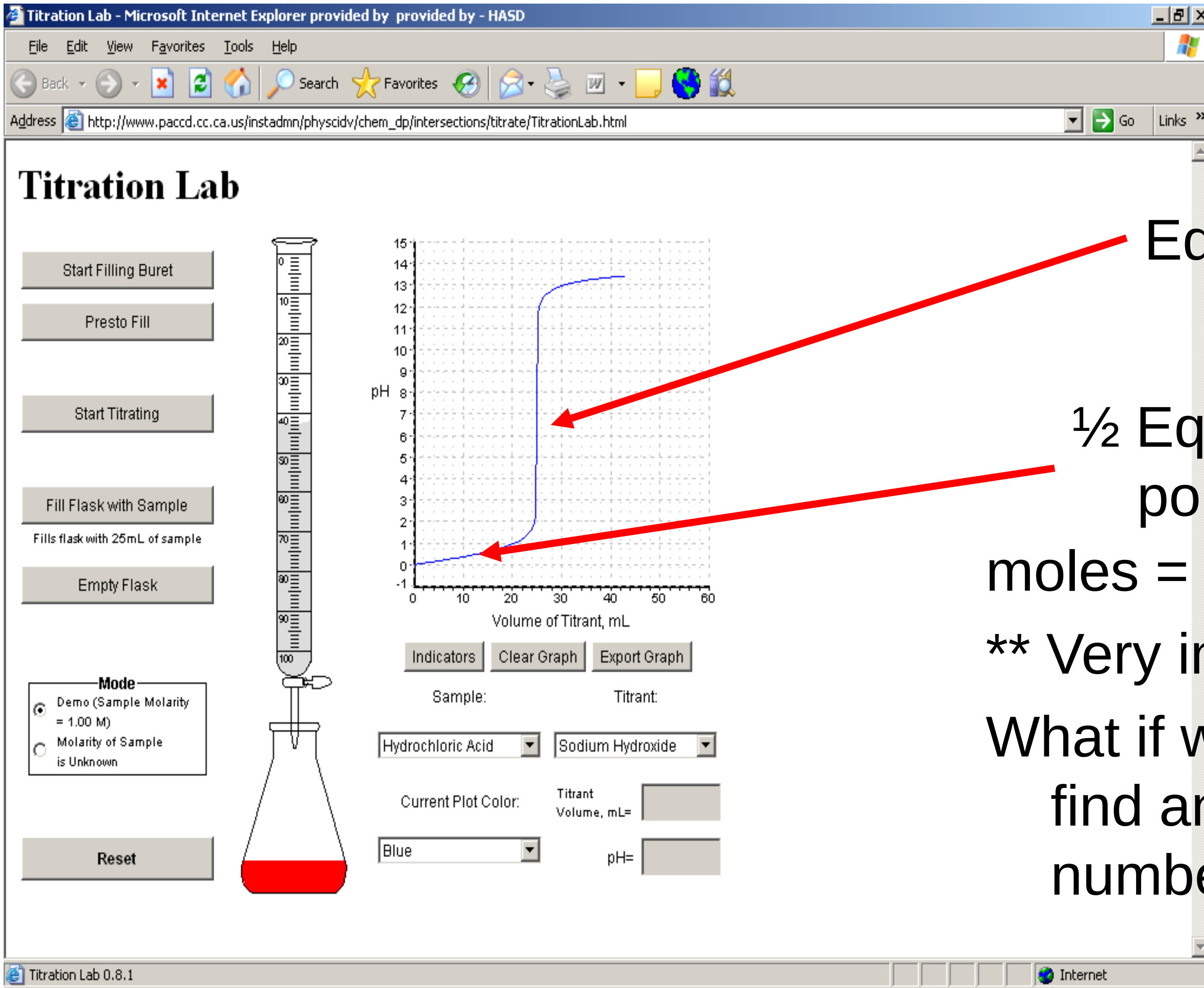
- .025 moles

- Indicator:

- Phenolphthalein is red

- Solution is now basic?

HCl vs. NaOH



Equivalence point

½ Equivalence point

moles = moles

** Very important**

What if we wanted to find an unknown number of moles?

What is happening at the half equivalence point

- HCl + NaOH => NaCl + H_2O

  .025mols
- ½ equivalence
- HCl + NaOH => NaCl + H_2O

  .0125mols .0125 moles
- Note the volume is now

25 + 12.5 = 37.5mL

What is happening at the equivalence point

- HCl + NaOH => NaCl + H_2O

  .025mols
- equivalence
- HCl + NaOH => NaCl + H_2O

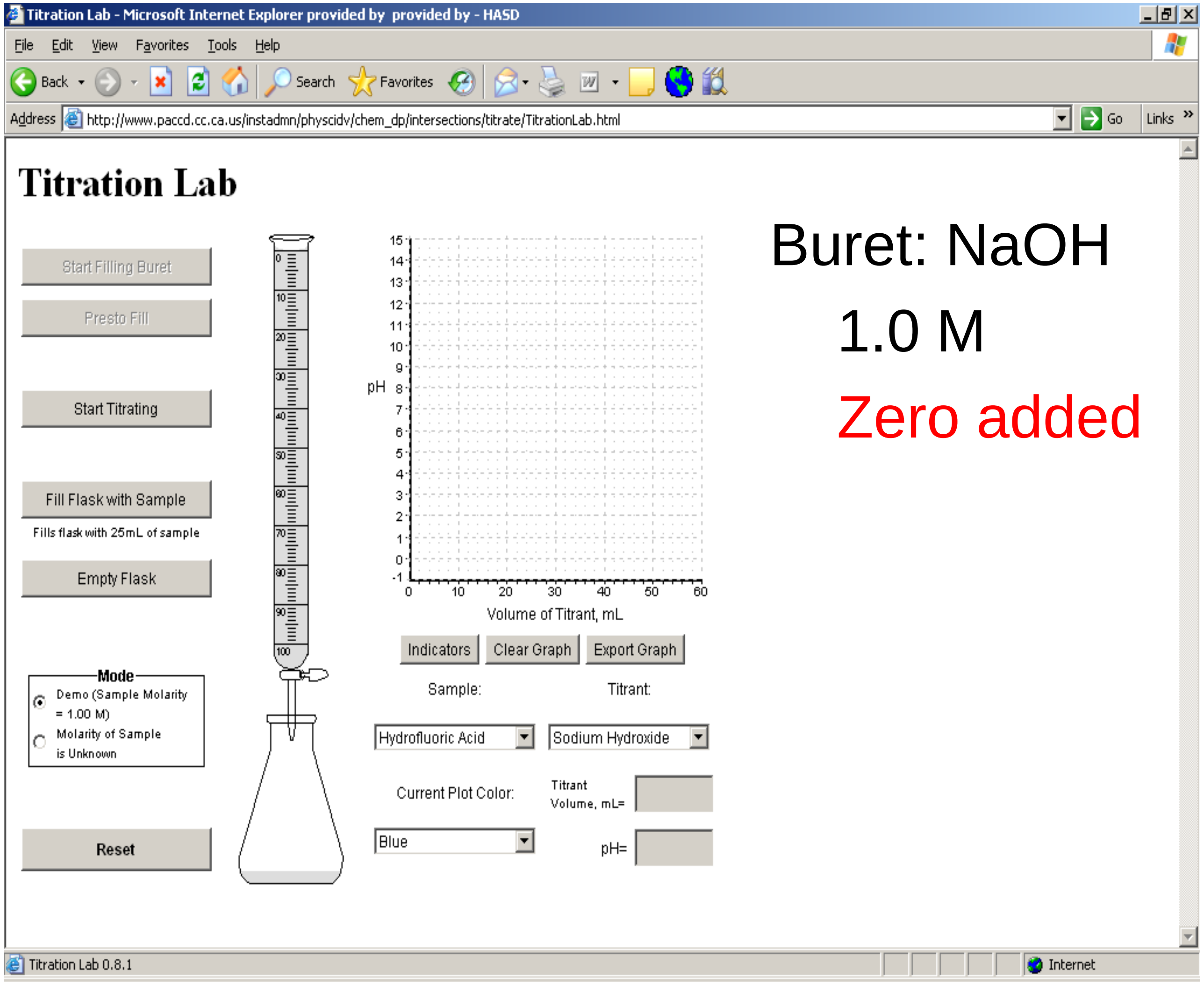
  .025 moles
- Note the volume is now

25 + 25 = 50 mL

HCl vs. NaOH

- Will our equivalency point always be at pH of 7?
  - At the equivalency point the original reactants are eliminated.
  - The only thing present in the solution is the products. In this case a neutral salt and water.
  - The pH of the salt determines the pH of the equivalency point.

HF vs. NaOH



Buret: NaOH

1.0 M

Zero added

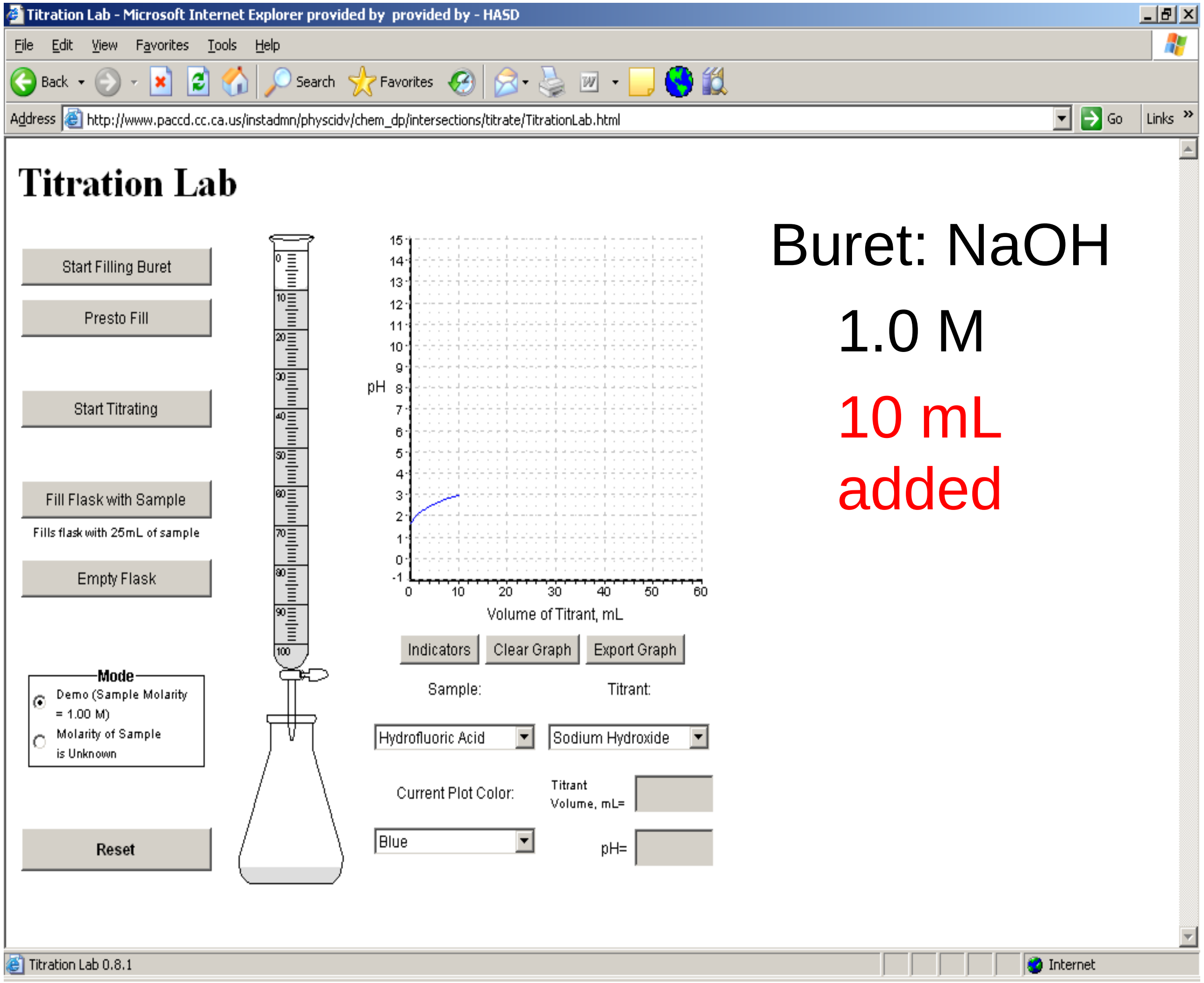
Flask:

- HF
- 1.0M
- 25 mL

Moles of HF

- .025 moles

HF vs. NaOH



Buret: NaOH

1.0 M

10 mL added

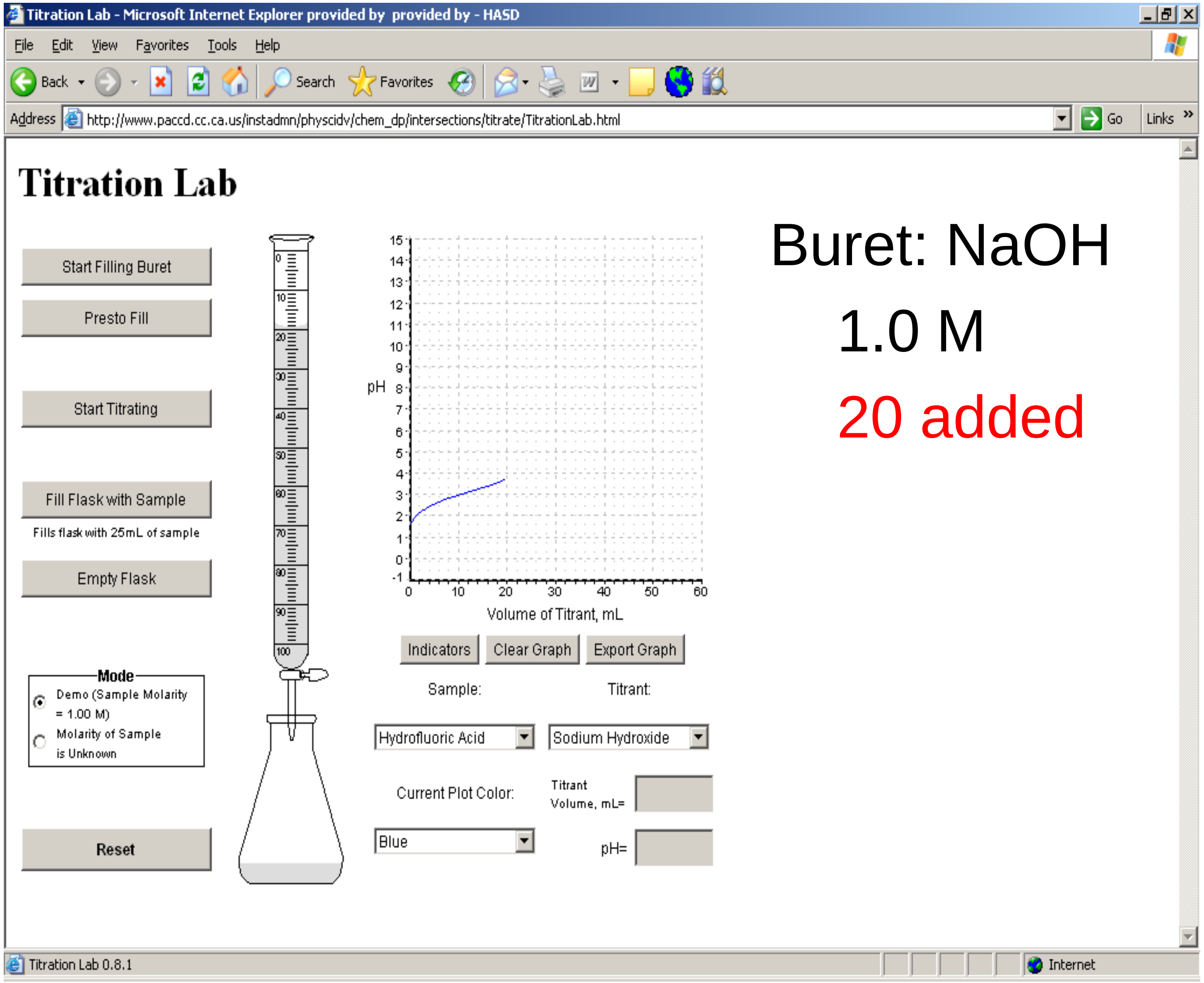
Flask:

- HF
- 1.0M
- 25 mL

Moles of HF

- .025 moles

HF vs. NaOH



Buret: NaOH

1.0 M

20 added

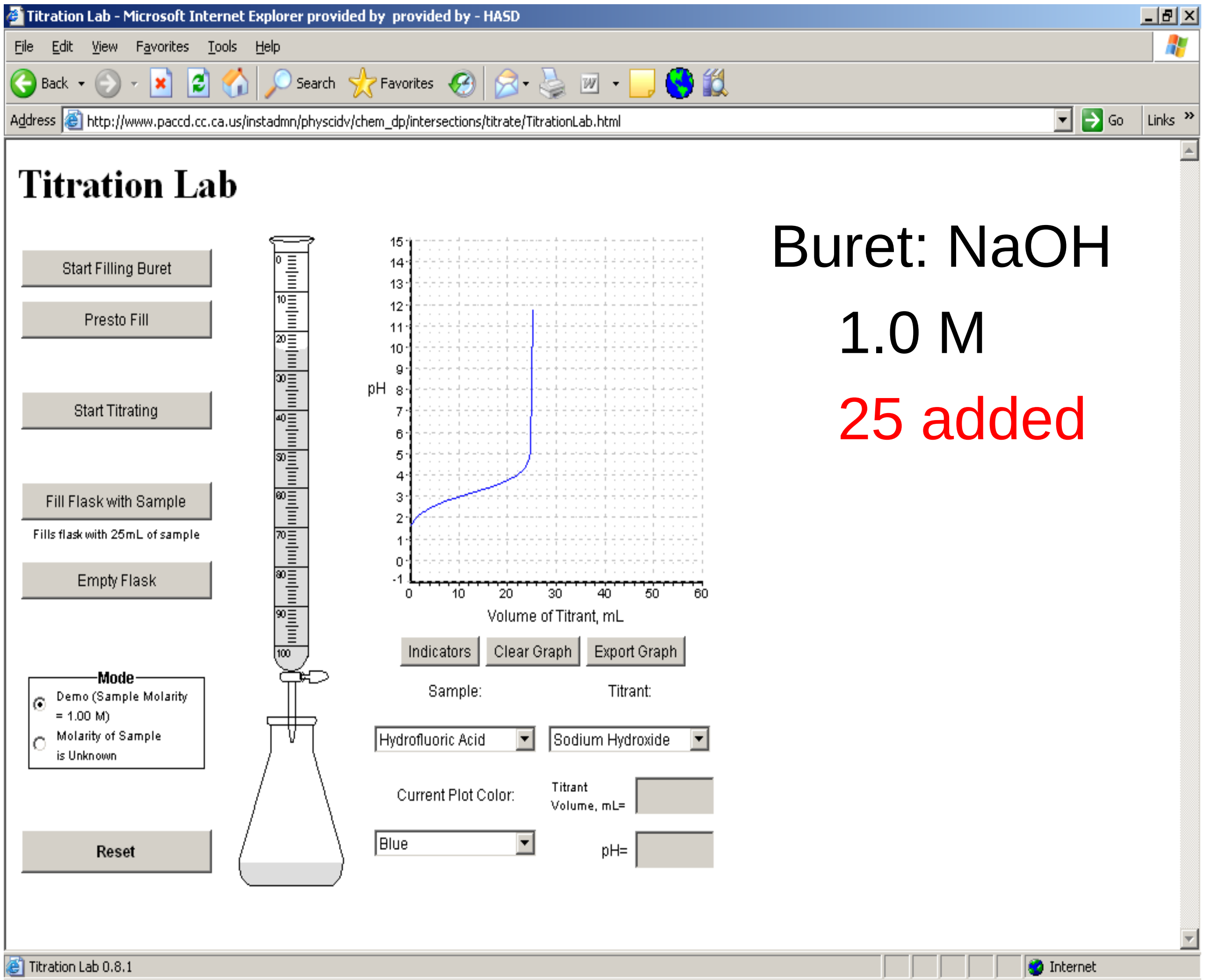
Flask:

- HF
- 1.0M
- 25 mL

Moles of HF

- .025 moles

HF vs. NaOH



Buret: NaOH

1.0 M

25 added

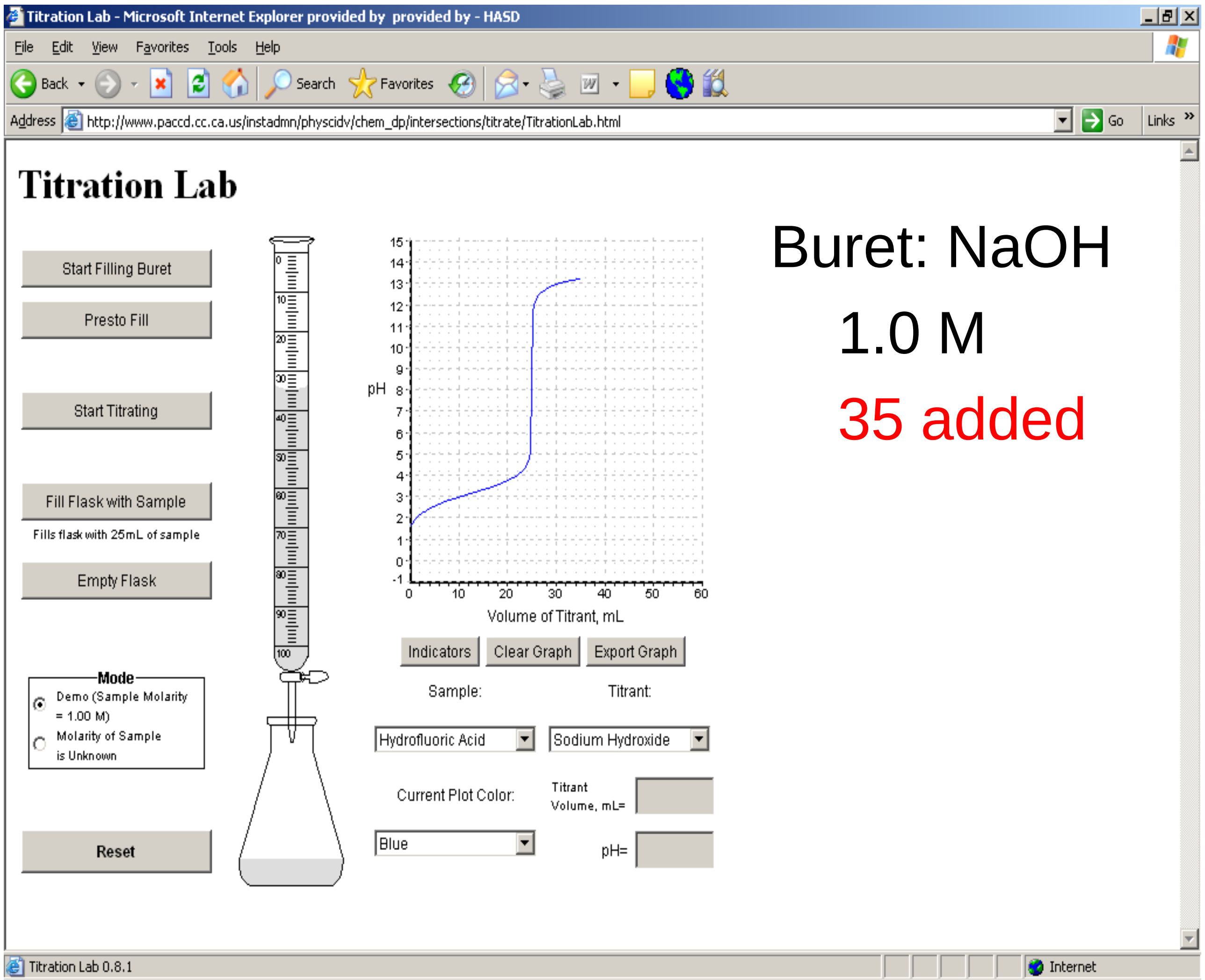
Flask:

- HF
- 1.0M
- 25 mL

Moles of HF

- .025 moles

HF vs. NaOH



Buret: NaOH

1.0 M

35 added

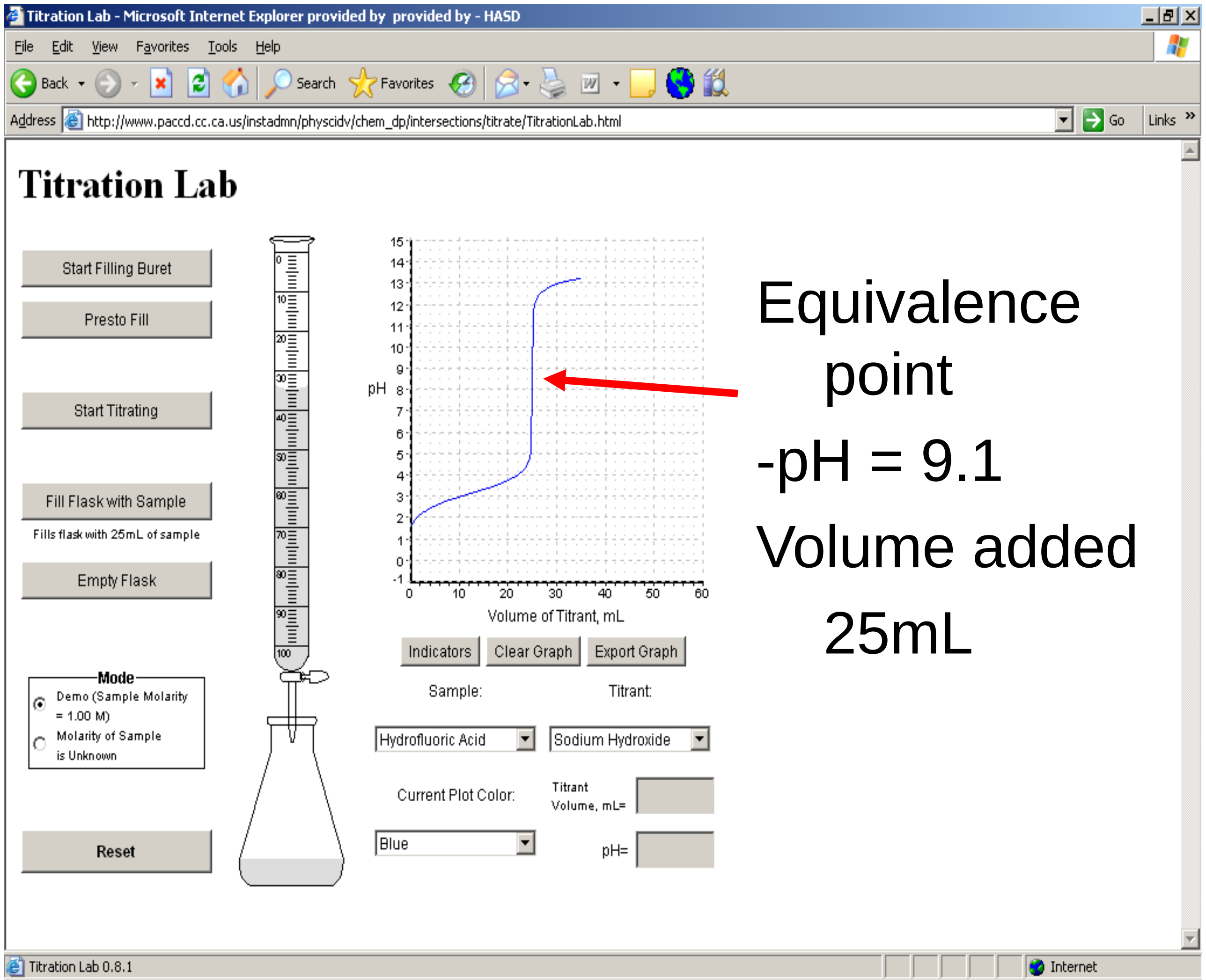
Flask:

- HF
- 1.0M
- 25 mL

Moles of HF

- .025 moles

HF vs. NaOH



Equivalence point

-pH = 9.1

Volume added

25mL

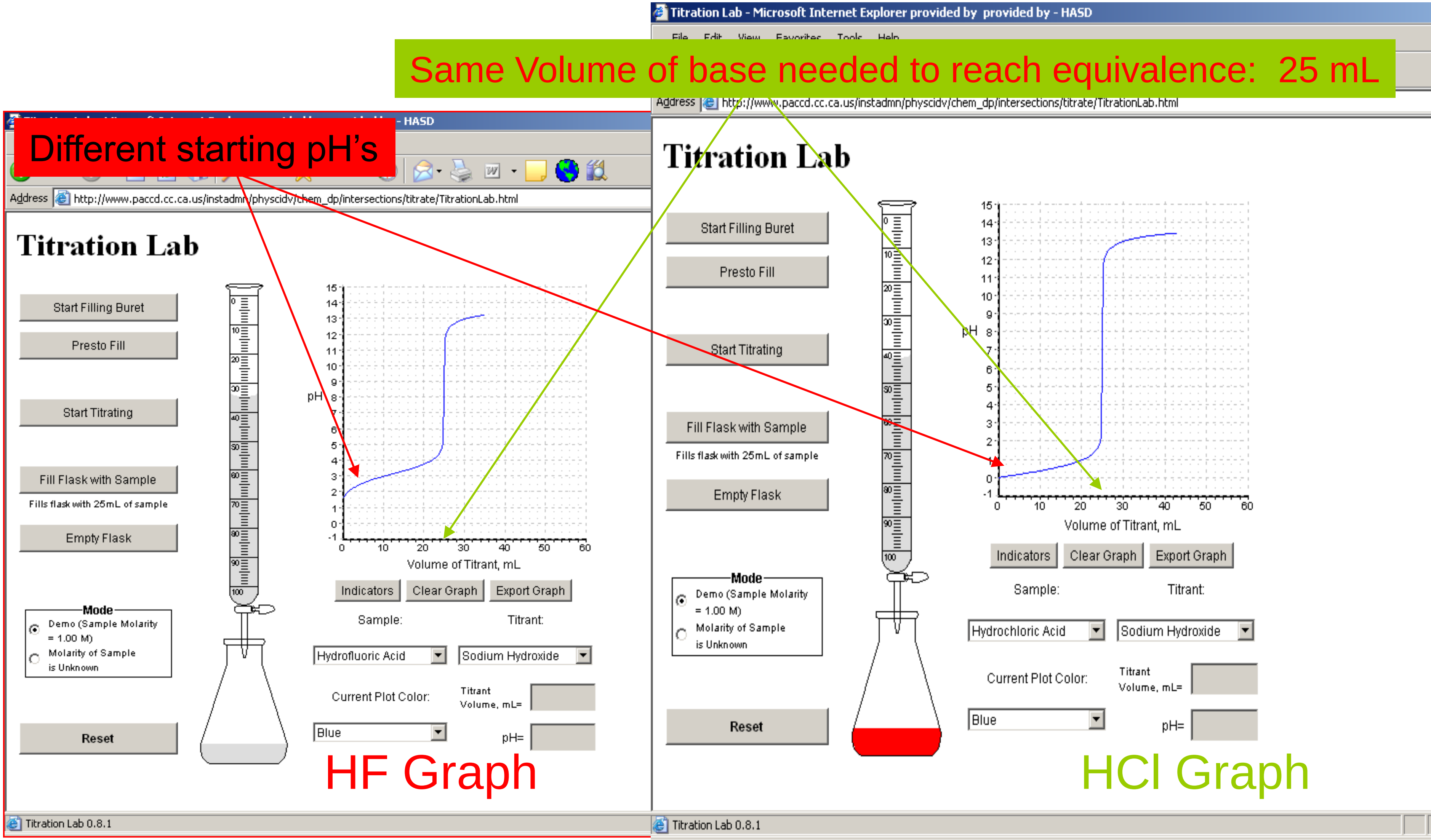
Flask:

- HF
- 1.0M
- 25 mL

Moles of HF

- .025 moles

What similarities or differences are there?



Why did both solutions hit the equivalency point after 25mL of base was added?

- Both acids, (HCl and HF) had the same volume and the same concentration. So they both contained the same number of Hydrogen ions.   .025mol
- HCl being a strong acid just ionizes 100% giving up all the H^+'s immediately where as the HF only does so after repeated neutralization.

Why do they have different starting pH's

- HCl is a stronger acid and will therefore produce H^+'s at a larger rate then the HF.

- Even though they have the same number of Hydronium ions the rate at which the are produced is different.

What is happening at the half equivalence point

- $HF + H_2O \Rightarrow F^- + H_3O^+$

  .025mols

  This is basic…
- ½ equivalence
- $HF \quad + \quad H_2O \quad \Rightarrow \quad F^- \quad + \quad H_3O^+$

  .0125mols .0125 moles
- Note the volume is now

25 + 12.5 = 37.5mL

How would you calculate the pH at this point?

Calcualting pH at ½ equiv.

- HF + H_2O => F^- + H_3O^+

	HF	F^-	H_3O^+
	$\frac{.0125\text{mols}}{.0375\text{L}}$	$\frac{.0125\text{ moles}}{.0375\text{L}}$	
I	.33M	.33M	0
Δ	-x	+x	+x
E	.33 –x	.33+x	x

Ka = .33 *x / .33

Ka = x

<u>NOTE: at ½ equivalence x = ka or ph = pka</u>

What is happening at the equivalence point

- HF + H_2O => F^- + H_3O^+

.025mols

- equivalence
- HF + H_2O => F^- + H_3O^+

.025 moles

- Note the volume is now

25 + 25 = 50 mL

My concentrations of F- = .025/.05L = .5M

How do you calculate the pH at the equivalence point????

- HF + H_2O => F^- + H_3O^+
- This is the acid hydrolysis but the acid is gone
- F^- + H_2O => HF + OH^-

	F^-	H_2O	HF	OH^-
I	.5M	-	0	0
Δ	-x		+x	+x
E	.5-x		x	x

Kb = x^2 / .5

-log x = pOH 14 – pOH = pH ☺

Polyprotic Titrations

- $H^+ + CO_3^{-2} \leftrightarrow HCO_3^{-1}$

  .025 mol
- $H^+ + HCO_3^{-1} \leftrightarrow H_2CO_3$

- We would expect to see two equivalence points here
- $H^+ = CO_3^{-2}$
- $H^+ = HCO_3^-$

Polyprotic Titrations

- Since we have .025 moles of CO_3^{-2} equivalence occurs when .025 moles of H+ and .05 moles of H^+ are added. This is equivalent to 25ml and 50 mL

Polyprotic Titrations

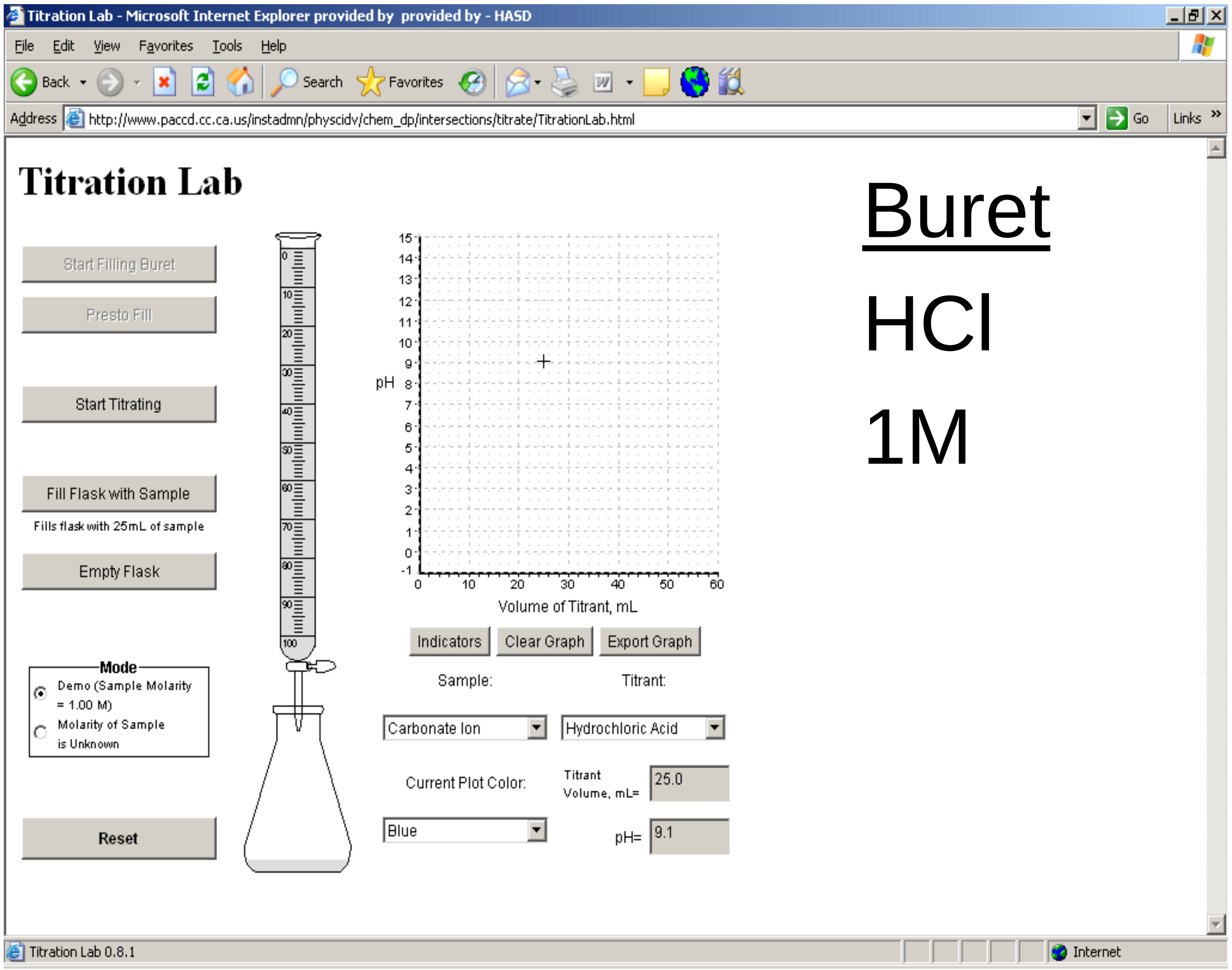
- $H^+ + CO_3^{-2} \leftrightarrow HCO_3^{-1}$

  .025 mol

- $H^+ + HCO_3^{-1} \leftrightarrow H_2CO_3$

- The Acid will fully protonate all of the CO_3^{-2} before starting to add a second hydrogen ion to the HCO_3^{-1}

Titration of a polyprotic acid
HCl vs. CO_3^{-2}



<u>Buret</u>

HCl

1M

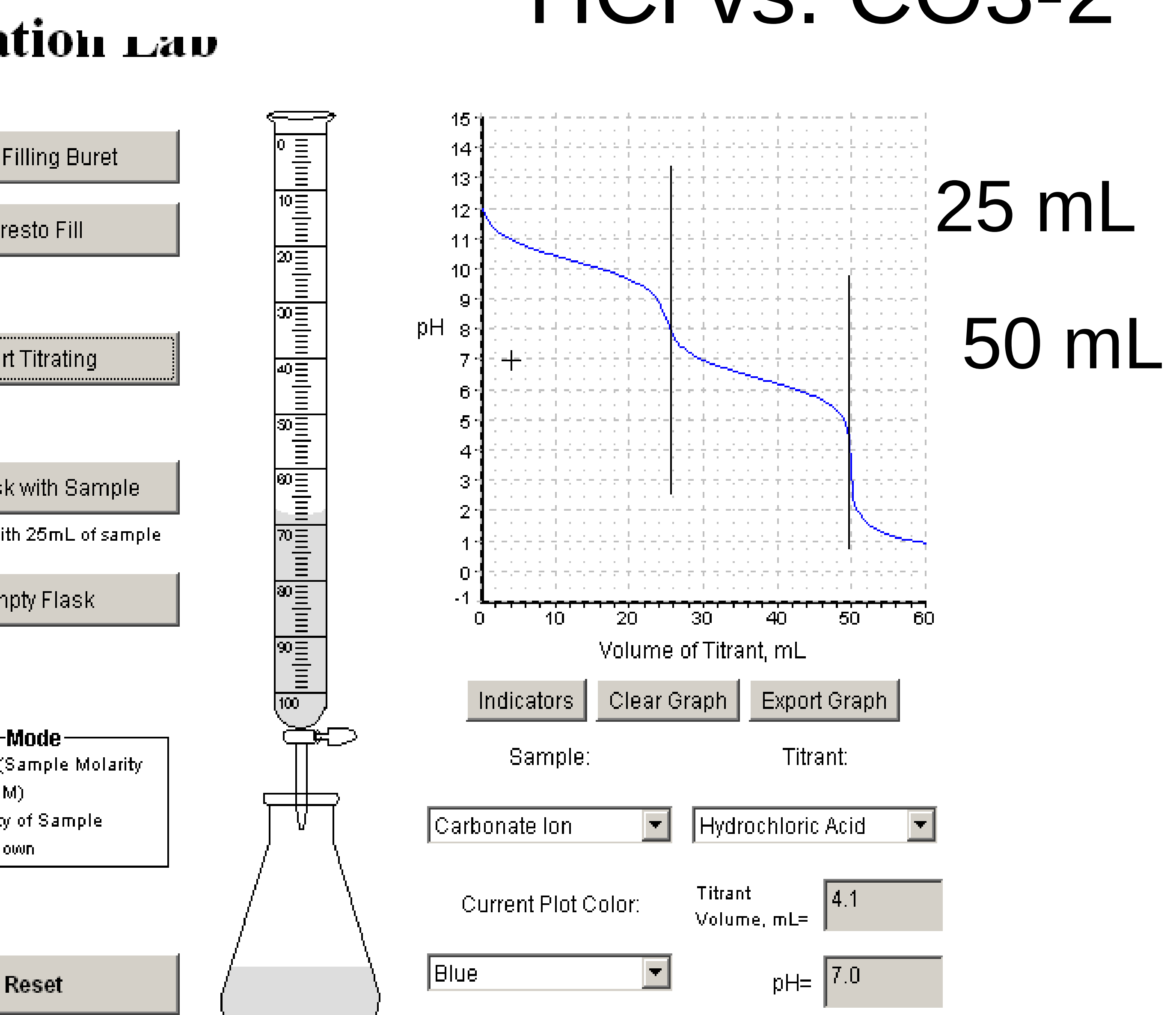
<u>Flask</u> CO_3^{-2}

25ml

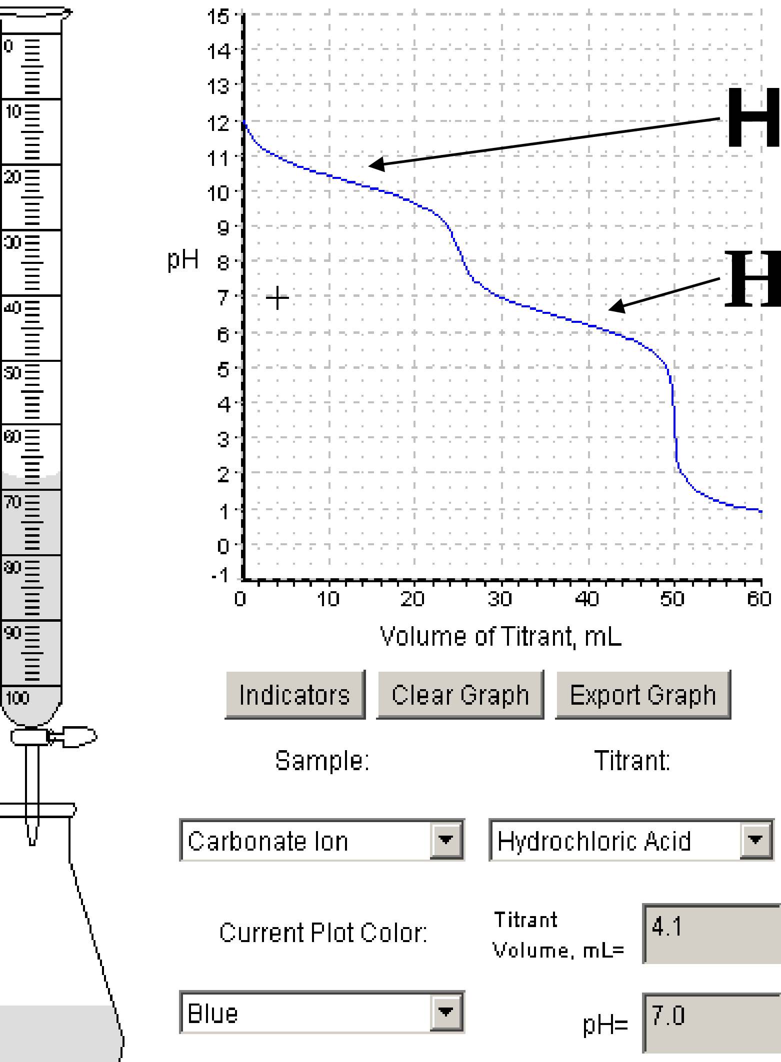
1M

= .025 mol

Titration of a polyprotic acid
HCl vs. CO3-2



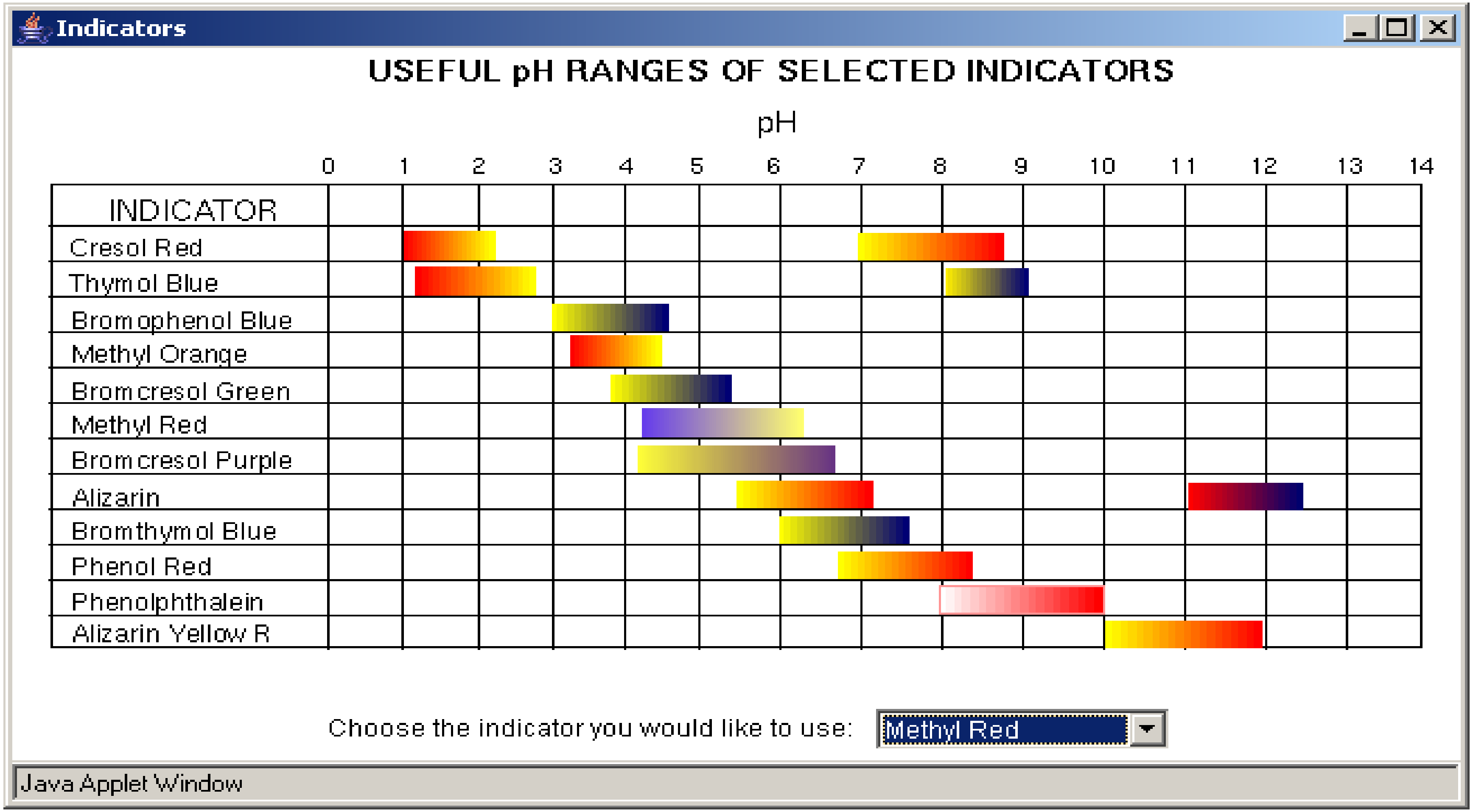
Titration of a polyprotic acid
HCl vs. CO3-2



$$H^{+} + CO_3^{-2} \leftrightarrow HCO_3^{-1}$$

$$H^{+} + HCO_3^{-1} \leftrightarrow H_2CO_3$$

Indicators


Indicators
USEFUL pH RANGES OF SELECTED INDICATORS
pH
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
INDICATOR
Cresol Red
Thymol Blue
Bromophenol Blue
Methyl Orange
Bromcresol Green
Methyl Red
Bromcresol Purple
Alizarin
Bromthymol Blue
Phenol Red
Phenolphthalein
Alizarin Yellow R
Choose the indicator you would like to use:
Methyl Red
Java Applet Window

Practice

- A sample of Acetic acid (100mL, 0.15M) has a pH of 2.78
- Write the hydrolysis equation for acetic acid.
- Write the equilibrium expression.
- What is the Ka for the sample?
- What is the pH at the equivalence?
- What mass of NaOH is needed to reach half equivalence?

Practice

- Write the hydrolysis equation for acetic acid.
- Write the equilibrium expression.

- $HC_2H_3O_2 + H_2O \Rightarrow H_3O^+ + C_2H_3O_2^-$

- $Ka = [H_3O^+][C_2H_3O_2^-] / [HC_2H_3O_2]$

What is the Ka for the sample?

What is the Ka for the sample?

	$HC_2H_3O_2$ +	H_2O =>	H_3O^+ +	$C_2H_3O_2^-$
I	.15	-	0	0
Δ	-x	-	+x	+x
E	.15-x	-	x	x

$X = 10^{-2.78} = .0016M$

$(.0016)^2/.15 = 1.77E-5$

What is the pH at the equivalence?

What is the pH at the equivalence

- $HC_2H_3O_2 + H_2O \Rightarrow H_3O^+ + C_2H_3O_2^-$

  .15M

  All reactant is converted to product.

What is the concentration of the product? If a liquid is added you must recalculate the concentrations

calculations

$C_2H_3O_2^- + H_2O \Rightarrow OH^- + HC_2H_3O_2$

I	.15	-	0	0
Δ	-x	-	+x	+x
E	.15-x	-	x	x

$Kb = [OH^-][HC_2H_3O_2^-] / [C_2H_3O_2^-]$

Solve for x

(you will have had to solve for Kb as well

Ka*Kb = Kw

What mass of NaOH is needed to reach half equivalence?

What mass of NaOH is needed to reach half equivalence?

- Since we started with .015 moles of acid we will half of those converted over to the conjugate base.

  $HC_2H_3O_2$ + H_2O => H_3O^+ + $C_2H_3O_2^-$

  .0075 .0075

1 OH^- can react with 1 $HC_2H_3O_2$. So we need .015 moles of NaOH

.0075mol * 44g/mol = .33g

Practice #2
Determining unknown molar mass an unknown solid acid.

- During a titration .500 grams of the solid acid was dissolved in 50 mL of water. The equivalence point was reached after 32.5mL of .1M NaOH was added.

- What is the molar mass of the unknown acid?

Determining unknown molar mass an unknown solid acid

- Molar mass = grams/ mol
- Grams = .500
- moles
  - M = mol/L .1 = x/.0325L x = .00325
  - .500/.00325 = 153. g/mol