pH and molarity

1 Formulas

$pH = -\log[H^+]$ (→ molarity)

→ pH为数值，没单位

$\text{molarity} = \frac{\text{mole}}{\text{volume}}$ (molarity → M / mol dm^{-3}; mole → mol; volume → dm^3)

→ $1\ dm^3 = 1000\ cm^3$

2 Mole concept 金句

① 加水不影响 no. of mole

② 加水至n倍 volume → molarity 变至$\frac{1}{n}$倍 (no. of mole 不变)

③ 抽$\frac{1}{n}$倍 volume的溶液 → no. of mole 变至$\frac{1}{n}$倍 (molarity 不变)

3 Questions

LEVEL I

0.1 mole of HCl completely dissolves in 200 cm^3 distilled water. Find the pH of solution.

$HCl \rightarrow H^+ + Cl^-$

0.1 mol ⇒ 0.1 mol

$pH = -\log[H^+]$

$= -\log(\frac{0.1}{0.2})$

$= 0.301$

LEVEL II

50 cm^3 of 0.1M H_2SO_4 → Find the solution pH.

1 : 2 : 1

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

0.1M ⇒ 0.2M

$pH = -\log[H^+]$

$= -\log 0.2$

$= 0.699$

LEVEL III

30 cm^3 of 0.1M H_2SO_4 vs 50 cm^3 of 0.1M H_2SO_4

Which one is more acidic?

Same

Both $[H^+] = 0.1M \times 2 = 0.2M$

molarity 不变 ⇒ volume 增加 H^+ 也会增加.

→ 总体浓度还是一样

30 cm^3 of 0.05M H_2SO_4 vs 80 cm^3 of 0.1M HNO_3

Which one is more acidic?

Same

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

0.05M → 0.1M

$HNO_3 \rightarrow H^+ + NO_3^-$

0.1M → 0.1M

LEVEL IV

80 cm^3 of 0.1M HCl is mixed w/ 40 cm^3 of 0.1M HCl

Find the resulting pH.

molarity 一样, volume 不同

→ 混在一起 molarity 不变

$HCl \rightarrow H^+ + Cl^-$

0.1M ⇒ 0.1M

$pH = -\log[H^+]$

$= -\log 0.1$

$= 1$

80 cm^3 of 0.1M HCl is mixed with 50 cm^3 of 0.1M HNO_3

先算两边 H^+ 的浓度

$HCl \rightarrow H^+ + Cl^-$

0.1M ⇒ 0.1M

$HNO_3 \rightarrow H^+ + NO_3^-$

0.1M ⇒ 0.1M

$pH = -\log[H^+]$

$= -\log 0.1$

$= 1$

80 cm^3 of 0.1M HCl is mixed w/ 80 cm^3 of 0.1M H_2SO_4

这道题得先算 H^+ 的 no. of mole (∵两种 acid 的 $[H^+]$ 不同)

$HCl \rightarrow H^+ + Cl^-$

$0.1 \times 0.08 = 0.008$ mol ⇒ 0.008 mol

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

$0.1 \times 0.08 = 0.008$ mol ⇒ 0.016 mol

$pH = -\log[H^+]$

$= -\log \frac{0.008 + 0.016}{0.016}$ ← 0.008 dm^3 + 0.008 dm^3

$= 0.824$

40 cm^3 of 0.15M H_2SO_4 is mixed w/ 60 cm^3 of 0.1M HNO_3

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

$0.15 \times 0.04 = 0.006$ mol ⇒ 0.012 mol

$HNO_3 \rightarrow H^+ + NO_3^-$

$0.1 \times 0.06 = 0.006$ mol → 0.006 mol

$pH = -\log[H^+]$

$= -\log(\frac{0.012 + 0.006}{0.1})$ ← 0.04 dm^3 + 0.06 dm^3

$= 0.745$

LEVEL V

The pH of 50 cm^3 HCl is 1.

How much water do we need to add to increase its pH value to 3?

original molarity: $1 = -\log[H^+]$, $[H^+] = 0.1M$

required molarity: $3 = -\log[H^+]$, $[H^+] = 0.001M$

→ $0.1M \times 0.05\ dm^3 = 0.005$ mol

$\frac{0.005\ mol}{0.005\ dm^3 + v} = 0.001M$

$0.005 = 0.00005 + 0.001v$

$v = 4.95\ dm^3$

The pH of 10 cm^3 H_2SO_4 is 2.

How much water do we need to add to increase its pH value to 4?

original molarity: $2 = -\log[H^+]$, $[H^+] = 0.01M$

required molarity: $4 = -\log[H^+]$, $[H^+] = 0.0001M$

→ $0.01M \times 0.01\ dm^3 = 0.0001$ mol → 不用因为 H_2SO_4 而乘2!
(已经计算了 H^+ 的浓度，而非 H_2SO_4 的浓度)

$\frac{0.0001\ mol}{0.01\ dm^3 + v} = 0.0001M$

$1 = 0.001 + v$ (→ 约 0.0001)

$v = 0.99\ dm^3$

LEVEL VI

concentration 有两种单位

→ mol dm^{-3} (molarity)

→ g cm^{-3} (density)

⇒ 要懂得两种单位之间的互换

0.1M HCl → Find its density in g cm^{-3}.

$0.1M = \frac{0.1\ mol}{1\ dm^3}$

$= \frac{0.1(35.5+1)g}{1000\ cm^3}$ (→ m = mol · Mr)

$= 0.00365\ g\ cm^{-3}$

80 cm^3 of 0.1M impure HCl contains 83% HCl by mass. (0.1M → 这个浓度包括了其他杂质)

Find the density of HCl.

mole of acids $= 0.08 \times 0.1 = 0.008$ mol

mass of HCl $= 0.008 \times 83\% \times 36.5 = 0.242g$ (0.008 × 83% = mole; 36.5 = Mr)

density of HCl $= \frac{0.242}{80} = 0.00303\ g\ cm^{-3}$

LEVEL VII

If 0.3g Na is reacted with 600 cm^3 of 0.1M H_2SO_4.

find the resulting pH.

2 : 1 : 1 : 1

$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$

$\frac{0.3g}{23.1} = 0.0130$ mol; $0.6 \times 0.1 = 0.06$ mol

⇓

required $H_2SO_4 = \frac{0.0130}{2} = 0.00649$ mol

⇓

H_2SO_4 is excess,

unused $H_2SO_4 = 0.06 - 0.00649$

$= 0.05351$ mol

⇒

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

0.05351 mol → 0.1070 mol

$pH = -\log[H^+]$

$= -\log \frac{0.1070}{0.6}$

$= 0.749$

If 3g Mg is reacted with 100 cm^3 of 0.1M HCl,

find the resulting pH.

1 : 2 : 1 : 1

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

$\frac{3g}{24.3} = 0.0123$ mol; $0.1 \times 0.1 = 0.01$ mol

⇓

required HCl = 0.0246 mol

⇓

All HCl is used up

⇓

pH = 7