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 → dm³)

↳ $1\ dm^3 = 1000\ cm^3$

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

$pH = -\log[H^+]$
$= -\log\left(\frac{0.1}{0.2}\right)$
$= 0.301$

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

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$	$HNO_3 \rightarrow H^+ + NO_3^-$
0.05M → 0.1M	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

$HCl \rightarrow H^+ + Cl^-$	$HNO_3 \rightarrow H^+ + NO_3^-$
0.1M ⇒ 0.1M	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)

$HCl \rightarrow H^+ + Cl^-$	$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$
$0.1 \times 0.08 = 0.008$ mol ⇒ 0.008 mol	$0.1 \times 0.08 = 0.008$ 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

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$	$HNO_3 \rightarrow H^+ + NO_3^-$
$0.15 \times 0.04 = 0.006$ mol ⇒ 0.012 mol	$0.1 \times 0.06 = 0.006$ mol → 0.006 mol

$pH = -\log[H^+]$
$= -\log\left(\frac{0.012 + 0.006}{0.1}\right)$ ← $0.04\ dm^3 + 0.06\ dm^3$
$= 0.745$

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	required molarity
$1 = -\log[H^+]$	$3 = -\log[H^+]$
$[H^+] = 0.1M$	$[H^+] = 0.001M$

↳ $0.1M \times 0.05\ dm^3 = 0.005$ 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	required molarity
$2 = -\log[H^+]$	$4 = -\log[H^+]$
$[H^+] = 0.01M$	$[H^+] = 0.0001M$

↳ $0.01M \times 0.01\ dm^3 = 0.0001$ 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 $g\ cm^{-3}$.

$0.1M = \frac{0.1\ mol}{1\ dm^3}$
$= \frac{0.1(35.5+1)g}{1000\ cm^3}$ ← $m = mol \cdot Mr$
$= 0.00365\ g\ cm^{-3}$

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 $= \underbrace{0.08 \times 83\%}_{mole} \times \underbrace{36.5}_{Mr} = 0.242g$
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
$2Na + H_2SO_4 \rightarrow Na_2SO_4 + H_2$
$\frac{0.3g}{24.3} = 0.0123$ mol; $0.6 \times 0.1 = 0.06$ mol
⇓
required $H_2SO_4 = 0.00615$ mol
⇓
H_2SO_4 is excess,
unused $H_2SO_4 = 0.06 - 0.00615$
$= 0.05385$ mol

⟹

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$
0.05385 mol → 0.1077 mol

$pH = -\log[H^+]$
$= -\log\frac{0.1077}{0.6}$
$= 0.746$

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 $H_2SO_4 = 0.0246$ mol
⇓
All H_2SO_4 is used up
⇓
$pH = 7$