Time of flight Mass Spec Calculations
Model Answers

① Calculate the velocity of an ion of mass 2.1×10^{-25} kg which has a kinetic energy of 12.1×10^{-18} J.

$KE = \frac{1}{2}mv^2$ $\quad \sqrt{\frac{KE}{0.5\times m}} = v$

$\sqrt{\frac{12.1\times10^{-18}}{0.5\times 2.1\times10^{-25}}} = v$ $\quad v = \underline{\underline{10735\,m/s}}$

② Calculate the velocity of an ion of mass 2.1×10^{-20} g which has a kinetic energy of 2.16×10^{-19} J.

$KE = \frac{1}{2}mv^2$ $\quad \sqrt{\frac{KE}{0.5\times m}} = v$ $\quad \frac{2.1\times10^{-20}}{1000} = 2.1\times10^{-23}$ kg

$\sqrt{\frac{2.16\times10^{-19}}{0.5\times 2.1\times10^{-23}}} = v$ $\quad v = \underline{\underline{143.4\,m/s}}$

③ Calculate the velocity of an Mg^{24} ion which has a kinetic energy of 12.1×10^{-18} J where avogadro's constant is 6.022×10^{23}.

one mole of Mg^{24} = 24g $\quad \frac{24}{6.02\times10^{23}} = 3.99\times10^{-23}$ g in one ion

$\frac{3.99\times10^{-23}}{1000} = \underline{3.99\times10^{-26}}$ kg in one ion $\quad KE = \frac{1}{2}mv^2$ $\quad \sqrt{\frac{KE}{0.5\times m}} = v$

$\sqrt{\frac{12.1\times10^{-18}}{0.5\times 3.99\times10^{-26}}} = v$ $\quad v = \underline{\underline{24628\,m/s}}$

④ Calculate the distance travelled by an Na^{23} ion which has a kinetic energy of 1.1×10^{-19} J and a time of flight of 0.001 seconds.

$\frac{23g}{1000} = 0.023kg$ $\frac{0.023}{6.02 \times 10^{23}} = 3.82 \times 10^{-26}$ kg of one ion of Na^{23}.

$KE = \frac{1}{2}mv^2$ $\sqrt{\frac{KE}{0.5 \times m}} = v$ $\sqrt{\frac{1.1 \times 10^{-19}}{0.5 \times 3.82 \times 10^{-26}}} = v$

$v = 2399.8$ m/s. $v = \frac{d}{t}$ $v \times t = d$

$2399.8 \times 0.001 = 2.40m$

⑤ Calculate the time of flight of a K^{39} ion that has a kinetic energy of 12.1×10^{-18} J when the distance of the flight tube is 80cm long.

$\frac{39g}{1000} = 0.039kg$ $\frac{0.039}{6.02 \times 10^{23}} = 6.48 \times 10^{-26}$ kg of one ion of K^{39}.

$KE = \frac{1}{2}mv^2$ $\sqrt{\frac{KE}{0.5 \times m}} = v$ $\sqrt{\frac{12.1 \times 10^{-18}}{0.5 \times 6.48 \times 10^{-26}}} = v$

$v = 19325$ m/s $v = \frac{d}{t}$ $\frac{d}{v} = t$

$\frac{0.80}{19325} = 4.14 \times 10^{-5}$ seconds

⑥ A sample of copper was found to contain two isotopes, Cu^{+63} and Cu^{+65}. All of the ions were accelerated to have a kinetic energy of 1×10^{-16} J, and travelled through a flight tube that was 0.80m long. The Cu^{+63} ions took 1.829×10^{-5}s to travel through the tube, how long did the Cu^{+65} take?

$KE = \frac{1}{2}mv^2$ $\quad \sqrt{\frac{KE}{0.5\times m}} = v$ $\quad \frac{65g}{1000} = 0.065$

$\frac{0.065}{6.02\times10^{23}} = 1.0797\times10^{-25}$ kg $\quad \sqrt{\frac{1\times10^{-16}}{0.5\times1.0797\times10^{-25}}} = v$

$v = 43038$ m/s $\quad v = \frac{d}{t}$ $\quad \frac{d}{v} = t$ $\quad \frac{0.80}{43038} = \underline{\underline{1.858\times10^{-5}\text{sec}}}$

⑦ A Ba^{+137} ion travels through a time of light tube with a kinetic energy of 3.23×10^{-16} J. This ion takes 2.62×10^{-5} seconds to reach the detector. Calculate the length of the flight tube.

$KE = \frac{1}{2}mv^2$ $\quad \sqrt{\frac{KE}{0.5\times m}} = v$ $\quad \frac{137g}{1000} = 0.137$kg

$\frac{0.137}{6.02\times10^{23}} = 2.276\times10^{-25}$ kg $\quad \sqrt{\frac{3.23\times10^{-16}}{0.5\times2.276\times10^{-25}}} = 53275.8$m/s

$v = \frac{d}{t}$ $\quad v\times t = d$ $\quad 53275.8\times2.62\times10^{-5} = \underline{\underline{1.396\text{m}}}$

(8) A sample of copper was analysed and found to have two isotopes Cu^{63} and Cu^{66}. All isotopes were accelerated and Cu^{+63} took 1.4242×10^{-5} s. How long would the Cu^{+66} ion take?

$$\frac{63g}{1000} = 0.063\,kg \qquad \frac{0.063}{6.02 \times 10^{23}} = 1.0465 \times 10^{-25}\,kg$$

Remember that KE of all isotopes are equal! ∴

$$KE = \tfrac{1}{2} mv^2 \qquad KE = 0.5 \times m \times \left(\frac{d}{t}\right)^2$$

$$\frac{66g}{1000} = 0.066 \qquad \frac{0.066}{6.02 \times 10^{23}} = 1.096 \times 10^{-25}\,kg$$

∴ Cu^{+63} $\qquad$ Cu^{+66}

Cancel down

$$\cancel{\tfrac{1}{2}} \times 1.0465 \times 10^{-25} \times \frac{\cancel{d^2}}{1.4242 \times 10^{-5\,2}} = \cancel{\tfrac{1}{2}} \times 1.096 \times 10^{-25} \times \frac{\cancel{d^2}}{t^2}$$

Same as $m \times \frac{1}{t^2}$ →

$$\frac{1.0465 \times 10^{-25}}{(1.4242 \times 10^{-5})^2} = \frac{1.069 \times 10^{-25}}{t^2}$$

$$\sqrt{\frac{(1.4242 \times 10^{-5})^2 \times 1.096 \times 10^{-25}}{1.0465 \times 10^{-25}}} = t \qquad t = \underline{\underline{1.457 \times 10^{-5}\,sec}}$$