1) We are told we have two isotopes of potassium. Let \( x \) = fractional abundance of K-39 and \( y \) = fractional abundance of K-41. We are given the isotopic masses. Then we know these two things:

i) \( 38.963707x + 40.961825y = 39.0983 \) (since the weighted average of the masses must equal the observed mass)

and

ii) \( x + y = 1.00 \). (Since the total abundance has to be 1.00 or 100%)

Solving this second equation for \( x \), we get: \( x = 1 - y \)

Substituting into the first equation, we get:

\[
38.963707(1-y) + 40.961825y = 39.0983 \Rightarrow 38.963707 - 38.963707y + 40.961825y = 39.0983.
\]

This yields: \( 1.998118y = 0.134593 \) and \( y = 0.0674 \) = fractional abundance of K-41 and \( x = 0.933 \) = fractional abundance of K-39.

2) Yes, a given mass of hydrogen would react with different masses of the two isotopes to yield HCl. That is, 1.00 g of hydrogen would react with 35 g of Cl-35, but 37 g of Cl-37 to yield the respective HCl compounds. However, no, this does not violate the law of constant proportions. 1.00 g of hydrogen will always react with 37 g of Cl-37 to give \( \text{H}^{37}\text{Cl} \), and 35 g of Cl-35 to give \( \text{H}^{35}\text{Cl} \) i.e. if the samples of chlorine are pure in their isotopic form (35 vs. 37), then the law if obeyed. Similarly, if we had natural chlorine (ca. 2:1::Cl-35:Cl-37), the law would also be obeyed.

3) Copper (II) sulfate pentahydrate has the formula \( \text{CuSO}_4\cdot5\text{H}_2\text{O} \); the monohydrate has formula \( \text{CuSO}_4\cdot\text{H}_2\text{O} \) (needed later), and the anhydrous compound as the formula \( \text{CuSO}_4 \). For the second part, look at the following equation with the masses inserted:

\[
\text{CuSO}_4\cdot5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 + 5\text{H}_2\text{O}
\]

\[
3.548g \quad 2.268g \quad (1.280 g) \quad (\text{obtained by conservation of mass})
\]

This last datum implies that each water is “worth” 1.280 g/5 = 0.2560 g so if the \( \text{CuSO}_4 \) had not lost the last water molecule, the monohydrate \( \text{CuSO}_4\cdot\text{H}_2\text{O} \) would mass 2.524 g.

4) While this problem can certainly be done using the mole concept (if you know it), we haven’t done that yet, so we need to find a different, more fundamental manner to do it.
Fortunately, the laws of constant proportions and conservation of mass come to our rescue.

We are told that 10.00 g of \( \text{XCl}_2 \) reacts with excess chlorine to produce 12.55 g of \( \text{XCl}_4 \). Written as an equation, with masses inserted, this becomes:

\[
\text{XCl}_2 + \text{Cl}_2 \rightarrow \text{XCl}_4
\]

\[
\begin{align*}
10.00 \text{ g} & \quad (2.55 \text{ g}) \quad 12.55 \text{ g} \\
\text{found by difference using conservation of mass}
\end{align*}
\]

Using the law of constant proportions, we can also say:

\[
\frac{2.55 \text{ g Cl}_2}{10.00 \text{ g XCl}_2} = \frac{70.9 \text{ amu Cl}_2}{x \text{ amu XCl}_2}
\]

which leads us to mass of \( \text{XCl}_2 \) being \( 278.04 \text{ amu} \).

The mass of \( \text{XCl}_2 \) is made up of the mass of \( \text{X} \) (unknown) + the mass of 2Cl (70.9 amu), so the mass of \( \text{X} = (278.04 - 70.9) \text{ amu} = 207.14 \text{ amu} \), making \( \text{X} = \text{Pb or lead} \). (And yes, lead does form both a dichloride (\( \text{PbCl}_2 \)) and a tetrachloride (\( \text{PbCl}_4 \)) but you didn’t need to know that or state that to be correct.)