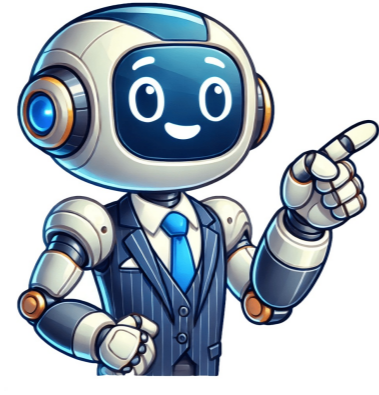


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Update: This article was updated on Sept. 11, 2017 by Rachel Ross, Live Science Contributor.Imagine plopping an atom down on a scale. As you do so, skin cells that are trillions of atoms thick flake off your hand and flutter down all around it, burying it in a pile of atomic doppelegangers. Meanwhile, moisture and atmospheric particles shoot about, bouncing on and off the scale and sending its atom-sensitive needle whipping back and forth like a windshield wiper. And by the way, how did you manage to isolate a single atom in the first place?A moment's thought shows you can't weigh an atom on a traditional scale.You may like instead, physicists for over a century have used an instrument called a mass spectrometer. Invented in 1912 by physicist J.J. Thomson and improved incrementally, it works like this: First, physicists "ionize" a gas of atoms by firing a beam of particles at the gas, which either adds electrons to the atoms in it or knocks a few of their electrons off, depending on the type of particle beam used. This gives the atoms now known as "ions" a net negative or positive electric charge.Next, the ions are sent through a tube in which they're subjected to electric and magnetic fields. Both of these fields exert a force on the ions, and the strengths of the two forces are proportional to the ions' charge (neutral atoms don't feel the forces). The electric force causes the ions to change speed, while the magnetic force bends their path.The ions are then collected by "Faraday cups" at the end of the tube, generating a current in wires attached to the cups. By measuring where and when the stream of ions hits the Faraday cups, the physicists can determine how much they must have accelerated, and in what direction, as a result of the electric and magnetic forces. Lastly, by way of Newton's second law of motion, F=ma, rearranged as m=F/a, the physicists divide the total force acting on the ions by their resulting acceleration to determine the ions' mass.The mass of the electron has also been determined using a mass spectrometer in that case, electrons were simply sent through the instrument themselves. That measurement enables physicists to determine the mass of an atom when it has the correct number of electrons, rather than a death or surplus of them.Get the works most fascinating discoveries delivered straight to your inbox.Using a mass spectrometer, physicists have determined the mass of a hydrogen atom to be 1.6735329(73) 10^-27 kilograms, where the parentheses don't mean "not known with complete certainty." That's accurate enough for most purposes. Good vibrationsAnother way that the mass of an atom can be found is by measuring its vibration frequency and solving backwards, according to an article in the Journal of Measurement Science.The vibration of an atom can be determined in a few ways, including atom interferometry, in which atomic waves coherently split and later recombined, according to Alex Cronin, an associate professor in the department of physics at the University of Arizona, and "frequency combs," which use spectrometry to measure vibrations. The frequency can then be used with the Planck constant to find the energy of the atom (E = hν, where h is the Planck constant and ν is the frequency). The energy can then be used with Einstein's famous equation, E = mc^2, to solve for the mass of the atom when it is rearranged to be = E/c^2.A third way to measure the mass of an atom is described in a 2012 article published in Nature Nanotechnology by J. Chaste, et al. This method involves using carbon nanotubes at low temperatures and in a vacuum and measuring how the vibration frequency changes depending on the mass of the particles attached to them. This scale can measure masses down to one yoctogram, less than the mass of a single proton (1.67 yoctograms).The test was with a 150-nanometer carbon nanotube suspended over a trench. The nanotube was plucked like a guitar string, and this produced a natural vibration frequency that was then compared to the vibration patterns when the nanotube came into contact with other particles. The amount of mass that is on the nanotube will change the frequency that is produced. Ye olde massWhat about before the days of mass spectrometers, when chemists were fuzzy about what an atom even was? Then, they primarily measured the weights of the atoms that composed various elements in terms of their relative masses, rather than their actual masses. In 1811, the Italian scientist Amedeo Avogadro realized that the volume of a gas (at a given pressure and temperature) is proportional to the number of atoms or molecules composing it, regardless of which gas it was. This useful fact allowed chemists to compare the relative weights of equal volumes of different gases to determine the relative masses of the atoms composing them. They measure atomic weights in terms of atomic mass units (amu), where one-twelfth of the mass of a carbon-12 atom is the standard. When in the second half of the 19th century, chemists used other means to approximate the number of atoms in a given volume of gas that famous constant known as Avogadro's number they began producing rough estimates of the mass of a single atom by weighing the volume of the whole gas, and dividing by the number. The Difference Between Atomic Weight, Mass and NumberMany people use the terms weight and mass interchangeably, and even most scales offer options in units such as pounds and kilograms. And while mass and weight are related, they are not the same thing. When discussing atoms, many people use atomic weight and atomic mass interchangeably, even though they aren't quite the same thing either.Atomic mass is defined as the number of protons and neutrons in an atom, where each proton and neutron has a mass of approximately 1 amu (1.0073 and 1.0087, respectively). The electrons within an atom are so minuscule compared to protons and neutrons that their mass is negligible. The carbon-12 atom, which is still used as the standard today, contains six protons and six neutrons for an atomic mass of twelve amu. Different isotopes of the same element (same element with different amounts of neutrons) do not have the same atomic mass. Carbon-13 has an atomic mass of 13 amu.Atomic weight, unlike the weight of an object, has nothing to do with the pull of gravity. It is a unitless value that is a ratio of the atomic masses of naturally occurring isotopes of an element compared with that of one-twelfth the mass of carbon-12. For elements such as beryllium or fluorine that only have one naturally occurring isotope, the atomic mass is equal to the atomic weight.Carbon has two naturally occurring isotopes carbon-12 and carbon-13. The atomic masses of each are 12.0000 and 13.0034, respectively, and knowing their abundances in nature (98.89 and 1.110 percent, respectively), the atomic weight of carbon is calculated to be about 12.01. The atomic weight is very similar to the mass of carbon-12 due to the majority of carbon in nature being made of the carbon-12 isotope.The atomic weight of any atom can be found by multiplying the abundance of an isotope of an element by the atomic mass of the element and then adding the results together. This equation can be used with elements with two or more isotopes:Carbon-12: 0.9889 x 12.0000 = 11.8669Carbon-13: 0.0111 x 13.0034 = 0.144311.8669 + 0.1443 = 12.0111 = atomic weight of carbonAnd there is still a third value that is used when discussing measurements related to atoms: atomic number. The atomic number is defined by the number of protons in an element. An element is defined by the number of protons the nucleus contains and doesn't have anything to do with how many isotopes the element has. Carbon always has an atomic number of 6 and uranium always has an atomic number of 92.Additional reporting by Rachel Ross, Live Science Contributor.Additional resources Download Article Learn how to get atomic mass with a formula or on the periodic table Download Article Atomic mass is the sum of all the protons, neutrons, and electrons in a single atom or molecule. However, the mass of an electron is so small, it is considered negligible and not included in the calculation. Though technically incorrect, the term is also often used to refer to the average atomic mass of all of the isotopes of one element. This second definition is actually the relative atomic mass, also known as the atomic weight, of an element.[1] The atomic weight takes into account the average of the masses of naturally occurring isotopes of the same element. Chemists need to distinguish between these two types of atomic mass to guide their work - an incorrect value for atomic mass can, for instance, lead to an incorrect calculation of an experiment's yield. To calculate the atomic mass of an individual atom, add the number of protons and neutrons together. Alternatively, check for the average atomic mass of an atom under the element's listing on the periodic table.1Understand how atomic mass is represented. Atomic mass, the mass of a given atom or molecule, can be expressed in standard SI mass units - grams, kilograms, etc. However, because atomic masses, when expressed in these terms, are incredibly small, atomic mass is often expressed in unified atomic mass units (usually shortened to "u" or "amu") or in Dalton's (Da). The standard for one atomic mass unit is equal to 1/12th of the mass of a standard carbon-12 isotope.[2]The atomic mass is the number of grams of the element in one mole of atoms of the element. This is a very useful property when it comes to practical calculations, as it allows easy conversion between the number of moles of a given quantity of atoms and the number of molecules of that quantity.2Locate atomic mass on the periodic table. Most standard periodic tables list the relative atomic masses (atomic weights) of all elements at the bottom of the element's square on the table, under its one or two letter chemical symbol. This number is usually expressed as a decimal rather than as a whole number.Note that the relative atomic masses listed on the periodic table are average values for the associated element. Chemical elements have different isotopes - chemical forms that differ in mass because of the addition or subtraction of one or more neutrons to the atom's nucleus. Thus, the relative atomic mass listed on the periodic table is suitable as an average value for atoms of a certain element, but not as the mass of a single atom of that element.Relative atomic masses, as listed on the periodic table, are used to calculate molar masses for atoms and molecules. Atomic masses, when expressed in amu, as on the periodic table, are technically unitless. However, by simply multiplying an atomic mass by 1 g/mol, a workable quantity is obtained for an element's molar mass - the mass (in grams) of one mole of an element's atoms.For example, the atomic mass of iron is 55.847 amu, which means one mole of iron atoms would weigh 55.847 grams. Advertisement 3Understand that periodic table values are an average atomic mass for an element. As has been noted, the relative atomic masses listed for each element on the periodic table are average values of all of an atom's isotopes. This average value is valuable for many practical calculations - like, for instance, calculating the molar mass of a molecule comprised of several atoms. However, when dealing with individual atoms, this number is sometimes insufficient.Because it's an average of several different types of isotopes, the value on the periodic table isn't the exact value for any single atom's atomic mass.The atomic masses for individual atoms must be calculated by taking into account the exact number of protons and neutrons in a single atom. Grasp isotopic mass differences. "I didn't get why isotopes of the same element had different atomic masses. The drawings here showing protons, neutrons, and electrons in the nucleus made it click more neutrons mean more mass! Now, isotope atomic masses make total sense." - Anudha N. Learn to calculate real atomic masses. "As a student, I got confused since the periodic table only gives average atomic masses. Working through the examples of finding exact masses using proton and neutron counts opened it up for me. Now, I can figure out atomic masses with no trouble!" - Peter M. Grasp what atomic mass actually is. "I wasn't sure what atomic mass really represents or how to calculate it. The clear summaries and step-by-step instructions here boosted my understanding a lot. I'm not confused anymore about this key chemistry idea." - George S. Understand a vital chemistry concept. "Not getting atomic mass made my chemistry homework so hard. But the friendly instructions and diagrams let me finally get what it is. Now, I can use my atomic mass knowledge to take on my work!" - Jessica K. Advertisement 1Find the atomic number of the element or isotope. The atomic number is the number of protons in an element, and never varies.[3] For example, all hydrogen atoms, and only hydrogen atoms, have 1 proton. Sodium has an atomic number of 11 because its nucleus has 11 protons, while oxygen has an atomic number of 8 because its nucleus has 8 protons. You can find the atomic number of any element on the periodic table - in nearly all standard periodic tables: it's the number above an element's 1 or 2-letter chemical symbol. This number will always be a positive whole number.Let's say that we're working with the carbon atom. Carbon always has 6 protons, so we know its atomic number is 6. We can also see on the periodic table that the square for carbon (C) has a "6" at the top, signifying that carbon's atomic number is 6.Note that an element's atomic number is 6.Note that an element's atomic number doesn't have any direct bearing on its relative atomic mass as listed on the periodic table.2Find the number of neutrons in the nucleus. The number of neutrons can vary among atoms of a certain element. While 2 atoms with the same number of protons and neutrons are both the same element, they are different isotopes of that element. Unlike the number of protons in an element, which never changes, the number of neutrons in atoms of a certain element can vary often enough that the average atomic mass of the element must be expressed as a decimal value between two whole numbers.The number of neutrons can be determined by the isotope designation of the element. For example, carbon-14 is a naturally occurring radioactive isotope of carbon-12. You will often see an isotope designated with the number as a superscript before the element symbol: 14C. The number of neutrons is calculated by subtracting the number of protons from the isotope number: 14 = 6 = 8 neutrons.Let's say the carbon atom we're working with has six neutrons (12C). This is by far the most common isotope of carbon, accounting for nearly 99% of all carbon atoms.[4] However, about 1% of carbon atoms have 7 neutrons (13C). Other types of carbon atoms with more or less than 6 or 7 neutrons exist in very small amounts.3Add the proton and neutron count. This is the atomic mass of that atom. Don't worry about the number of electrons orbiting the nucleus - their combined mass is very, very small, so, in most practical cases, it won't significantly affect your answer.[5]Our carbon atom has 6 protons + 6 neutrons = 12. The atomic mass of this specific carbon atom is 12. If it was a carbon-13 isotope, on the other hand, we would know that it has 6 protons + 7 neutrons = an atomic weight of 13.The actual atomic weight of carbon-13 is 13.003355(6), and is more precise because it was determined experimentally.Atomic mass is very close to the isotope number of an element. For basic calculation purposes, isotope number is equal to atomic mass. When determined experimentally, the atomic mass is slightly higher than the isotope number due to the very small mass contribution from electrons. Advertisement 1Determine which isotopes are in the sample. Chemists often determine the relative proportions of isotopes in a given sample by using a special tool called a mass spectrometer. However, at student-level chemistry, this information is often provided for you on school tests, etc., in the form of established values from scientific literature.For our purposes, let's say we're working with the isotopes carbon-12 and carbon-13.Determine the relative abundance of each isotope in the sample. Within a given element, different isotopes appear in different proportions. These proportions are almost always expressed as percentages. Some isotopes will be very common, while others will be very rare - at times, so rare that they can barely be detected. This information can be determined through mass spectrometry or from a reference book.Let's say that the abundance of carbon-12 is 99% and the abundance of carbon-13 is 1%. Other carbon isotopes do exist, but they exist in quantities so small that, for this example problem, they can be ignored.3Multiply the atomic mass of each isotope by its proportion in the sample. Multiply the atomic mass of each isotope by its percent abundance (written as a decimal). To convert a percentage to a decimal, simply divide it by 100. The converted percentages should always add up to 1.Our sample contains carbon-12 and carbon-13. If carbon-12 makes up 99% of the sample and carbon-13 makes up 1% of the sample, multiply 12 (the atomic mass of carbon-12) by 0.99 and 13 (the atomic mass of carbon-13) by 0.01.A reference book will give percent proportions based on all the known amounts of an element's isotopes. Most chemistry textbooks include this information in a table at the end of the book. A mass spectrometer can also yield the proportions for the sample being tested.4Add the results. Sum the products of the multiplications you performed in the previous step. The result of this addition is the relative atomic mass of your element - the average value of the atomic masses of your element's isotopes. When discussing an element in general, and not specific isotopes of that element, this value is used.In our example, 12 x 0.99 = 11.88 for carbon-12, while 13 x 0.01 = 0.13 for carbon-13. The relative atomic mass of our example is 11.88 + 0.13 = 12.01. Advertisement Add New Question Question How do I find the mass number of an atom? Add the protons and neutrons together to find the mass, or add the masses of the isotopes multiplied by the atom's natural abundance. Question If 1 amu is 1/12 of a carbon 12 atom, why is it that when I add the masses of the individual parts of a carbon 12 atom, I get more than 12 amu? 1 u = 1/12 the mass of carbon 12 by definition. You're adding the masses of uncombined protons and neutrons, 1.0073 u and 1.0087 u respectively. But when those particles fuse together to form an atom, some of the mass is converted into energy according to E=mc^2. The lost mass is called the "mass defect", and the equivalent amount of energy is the "binding energy." Question How can I find the mass of any atom to convert it in a.m.u.? We can find the mass of any atom by adding the electrons, protons and neutrons. See more answers Ask a Question Advertisement Chemistry reference bookCalculator This article was co-authored by Sean Alexander, MS. Sean Alexander is an Academic Tutor specializing in teaching mathematics and physics. Sean is the Owner of Alexander Tutoring, an academic tutoring business that provides personalized studying sessions focused on mathematics and physics. With over 15 years of experience, Sean has worked as a physics and math instructor and tutor for Stanford University, San Francisco State University, and Stanbridge Academy. He holds a BS in Physics from the University of California, Santa Barbara and an MS in Theoretical Physics from San Francisco State University. This article has been viewed 989,517 times. Co-authors: 60 Updated: December 6, 2024 Views:989,517 Categories: Chemistry Calculations PrintSend fan mail to authors Thanks to all authors for creating a page that has been read 989,517 times. "As a student, I got confused since the periodic table only gives average atomic masses. Working through the examples of finding exact masses using proton and neutron counts opened it up for me. Now, I can figure out atomic masses with no trouble!" ... " more Share your Story Download Article Learn how to get atomic mass with a formula or on the periodic table Download Article Atomic mass is the sum of all the protons, neutrons, and electrons in a single atom or molecule. However, the mass of an electron is so small, it is considered negligible and not included in the calculation. 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The lost mass is called the "mass defect", and the equivalent amount of energy is the "binding energy." Question How can I find the mass of any atom to convert it in a.m.u.? We can find the mass of any atom by adding the electrons, protons and neutrons. See more answers Ask a Question Advertisement Chemistry reference bookCalculator This article was co-authored by Sean Alexander, MS. Sean Alexander is an Academic Tutor specializing in teaching mathematics and physics. Sean is the Owner of Alexander Tutoring, an academic tutoring business that provides personalized studying sessions focused on mathematics and physics. With over 15 years of experience, Sean has worked as a physics and math instructor and tutor for Stanford University, San Francisco State University, and Stanbridge Academy. He holds a BS in Physics from the University of California, Santa Barbara and an MS in Theoretical Physics from San Francisco State University. This article has been viewed 989,517 times. Co-authors: 60 Updated: December 6, 2024 Views:989,517 Categories: Chemistry Calculations PrintSend fan mail to authors Thanks to all authors for creating a page that has been read 989,517 times. "As a student, I got confused since the periodic table only gives average atomic masses. Working through the examples of finding exact masses using proton and neutron counts opened it up for me. Now, I can figure out atomic masses with no trouble!" ... " more Share your story Atomic mass in an atom or group of an atom is the sum of the masses of protons, neutrons and electrons. The electrons have very less mass in comparison to protons or neutrons so the mass of electrons is not influenced in calculating. For an element, relative atomic mass of the naturally occurring isotopes of that element relative to the mass of an atom of 12C. Which meansone atom is given a relative atomic mass of exactly 12. Atomic mass is not reported with unit. The formula for atomic mass is given belowAtomic mass = Mass of protons + Mass of neutrons + Mass of electronsHow to Calculate Atomic Mass?Therearethreeways to calculate theatomicmass,dependingontheir circumstancesofeach. In the periodic table digit of an atomic massusuallymarkedunderrepresentationofan element.For exampleHydrogen (H) atomic mass -3Periodic Table In an element atomic mass of an atom can be calculated by adding the mass of protons and neutrons.3.All atoms of an Element Weighted Average3. Weight average of an elementTheweightedaverageoftheisotopesofeach elementgroundedinnaturebytheirabundanceis theatomicweightofan element. One can calculate the atomic mass of the element with these tips. A list of isotopes with natural abundance and mass is given either as a percentage or decimal value. Each isotopes-abundance is multiplied by its mass. If isotope abundance is present their solution should be divided by 100 and add these values.The solution means the atomic mass of the specific element. the atomic mass unit can be related with the other mass unit by using theconversion factor.1u = 1.66054 x 10^-24g. The atomic mass of a few substances is tabulated below.SubstanceAtomic massCalcium ion40.1Chloride ion35.5Magnesium ion24.3Potassium ion39.1Relative Atomic MassThe link between the mass of an element and the number of atoms it contains is the relative atomic mass of the element. By using this chemists work out the chemical formula. The relative atomic mass scale is used to compare the masses of different atoms.First the hydrogen atom the lightest atom was originally assigned a relative atomic mass of 1 and the relative atomic mass of other atoms was compared with this.ElementRelative atomic massCarbon12Hydrogen1Oxygen16Magnesium24Nitrogen14Atomic Mass ProblemsProblem 1Find the element mass number whose atomic number is 19 and the neutron number is 20.Solution: Number of protons = 19Number of Neutrons = 20Atomic mass Number = Number of protons + number of neutronsA = 20 + 19Mass number (A) = 39 Atomic, Molecular and Equivalent masses (1) Atomic mass : It is the average relative mass of atom of element as compared with an atom of carbon 12 isotope taken as 12. \(\text{Atomic mass} = \frac{\text{Atomic mass of an atom}}{\text{Atomic mass of an atom of } ^{12}\text{C}}\)(ii) Average atomic mass : If an element exists in two isotopes having atomic masses a and b in the ratio m : n, then average atomic mass =\(\frac{m(a+n)+n(b)}{m+n}\) Since the atomic mass is a ratio, it has no units and is expressed in amu, 1 amu = \(\frac{1}{1836}\)times \((10)^{-24}\)Jg. One atomic mass unit (amu) is equal to \(\frac{1}{12}\)th of the mass of an atom of carbon-12 isotope. Gram atomic mass (GAM) : Atomic mass of an element expressed in grams is called Gram atomic mass or gram atom or mole atom. (i) Number of gram atoms =\(\frac{\text{Mass of an element}}{\text{GAM}}\)(ii) Mass of an element in gm. = No. of gm. atom \(\times\) times \(\times\) GAM (iii) Number of atoms in 1 GAM = 6.02 \(\times\) 10^23 \(\times\) \(\frac{\text{Volume of atoms in a given substance}}{\text{No. of GAM}}\)(iv) Important generalisations Number of atoms in a substance = Number of GAM \(\times\) times \(\times\) 6.02 \(\times\) 10^23 \(\times\) times \(\times\) Atomicity Number of electrons in given substance = Number of GAM \(\times\) times \(\times\) 6.02 \(\times\) 10^23 \(\times\) times \(\times\) Number of electrons Methods of determination of molecular mass Following methods are used to determine molecular mass. (i) Diffusion method (For gases). The ratio of rates of diffusion of two gases is inversely proportional to the square root of their molecular masses. \(\frac{r\_1}{r\_2} = \sqrt{\frac{M\_2}{M\_1}}\)(ii) Graham's method : Mass of a fixed volume of the vapour is compared with the mass of the same volume of hydrogen under same conditions. The ratio of these masses is called Vapour density or Relative Density. \(\frac{\text{Molecular mass}}{\text{Molecular mass of H}\_2} = \frac{\text{Vapour density}}{\text{Vapour density of H}\_2}\)(iii) Victor Meyer method (For volatile liquids or solids) It is based on Dalton's law of partial pressure and Avogadro's hypothesis (gram molar volume). 22400 ml of vapours of a substance = Molecular mass of that substance (iv) Colligative property method (For non-volatile solids) Discussed in colligative properties. Average atomic mass and molecular mass \(\overline{A} = \frac{\sum A\_i \times X\_i}{\sum X\_i}\)(v) EM of an oxidising agent \(\frac{\text{EM of an oxidising agent}}{\text{EM of an element}} = \frac{\text{Equivalent mass}}{\text{Atomic mass}}\)(vi) EM of a base \(\frac{\text{EM of a base}}{\text{EM of an element}} = \frac{\text{Equivalent mass}}{\text{Atomic mass}}\)(vii) EM of a salt \(\frac{\text{EM of a salt}}{\text{EM of an element}} = \frac{\text{Equivalent mass}}{\text{Atomic mass}}\)(viii) Conversion method : When one compound of an element is converted to another compound of the same metal, then \(\frac{\text{Atomic mass of compound I}}{\text{Atomic mass of compound II}} = \frac{\text{Equivalent mass of compound I}}{\text{Equivalent mass of compound II}}\)(ix) Volatile chloride method : \(\frac{\text{Atomic mass of element}}{\text{Atomic mass of chlorine}} = \frac{\text{Equivalent mass of element}}{\text{Equivalent mass of chlorine}}\)(x) Silver salt method (For organic acids) \(\frac{\text{Equivalent mass of acid}}{\text{Equivalent mass of silver salt}} = \frac{\text{Equivalent mass of acid}}{\text{Equivalent mass of silver salt}}\)(xi) EM of an acid \(\frac{\text{EM of an acid}}{\text{EM of an element}} = \frac{\text{Equivalent mass of acid}}{\text{Equivalent mass of element}}\)(xii) EM of a base \(\frac{\text{EM of a base}}{\text{EM of an element}} = \frac{\text{Equivalent mass of base}}{\text{Equivalent mass of element}}\)(xiii) EM of a salt \(\frac{\text{EM of a salt}}{\text{EM of an element}} = \frac{\text{Equivalent mass of salt}}{\text{Equivalent mass of element}}\)(xiv) EM of an oxidising agent \(\frac{\text{EM of an oxidising agent}}{\text{EM of an element}} = \frac{\text{Equivalent mass}}{\text{Atomic mass}}\)(xv) EM of a reducing agent \(\frac{\text{EM of a reducing agent}}{\text{EM of an element}} = \frac{\text{Equivalent mass}}{\text{Atomic mass}}\)(xvi) EM of a metal \(\frac{\text{EM of a metal}}{\text{EM of an element}} = 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