



# Basics of modern modeling and expansion of the relativity theory of time in the field of classical physics

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## Abstract

Throughout history, many scientists considered time as the result of changing the world and believed that time is not true. Among those who say that time is not true, Einstein is the only one who was able to mathematically explain the relativity of time in the field of geometry (space time) and present his equations in relativistic physics. Although Einstein, like other scientists, did not provide a clear definition of time, he presented the relativity of time well. He showed that time is not independent of space and bends along with space. Also, Einstein used the speed of light to convert mass into energy to introduce the law of mass–energy equivalence. Currently, basic laws such as conservation of mass, conservation of energy and equivalence of mass and energy have been presented. Recently, due to the importance of time in the development of science, especially in the field of water and chemistry, “timemass equivalence law” has also been presented (by the author). In this research, with the aim of expanding the relativity of time in the flows of mass and energy (not the field of motion and geometry), while presenting new definitions of “phenomenon”, “time” and “specific speed of transformation”, in addition to the theory of “mass equivalence law” “Time” was completed, the general equations of equivalence of energy time—and timemass were introduced. Then, to check the results more accurately, the general masstime equation (in this study, absorption kinetics) by performing surface absorption experiments of heavy metals (Fe + 2, Pb + 2, Zn + 2, Ni + 2, Cd + 2, Cu + 2)) was investigated by the adsorbents of green walnut shell (GWH) and its biochar (GWHB), and the results are tested in different ways.

**Keywords** Time–mass (energy) equivalence law · Relativity expansion of time · Specific speed of transformation · General kinetic model

## Introduction

The truth of time has been debated for more than two centuries. Scientists like Leibniz, Einstein, Rowley, Wheeler and DeWitt believe that time is the result of changing the world and has no inherent originality. Although they all consider time as an illusion, none of them have given a clear definition of time (Butterfield 2010; Jackson (2018); ; ; Scientific American Special Edition 2012). Einstein showed that time is relative and presented the theory of special relativity and then the theory of general relativity in the field of geometry. He was able to provide new definitions and important mathematical models, including the law of space and time (Shamohammadi and Shamohammadi 2024).

Einstein showed that space is not flat and has a topography of space–time. According to the theory of general relativity, space–time lines are bent as they approach the centers of gravity of mass and energy; as a result, clock hands move slower (time dilation). This issue is also done in the case of light, which is one of the subsets of space itself. Studies show that 94% of space consists of mass and energy (Sun-tola 2015; Valev 2014) and this property of space causes its curvature.

In general relativity, every particle of space has its own time, which is stationary relative to the same particle. Therefore, for a moving particle there is a special time relative to which the particle is always stationary. As a result, the specific time measured relative to the internal clock of the particle is not necessarily equal to the time measured by the observer with his clock (Scano 2024; Bhardwaj 2016).

In terms of general relativity, space–time has 4 dimensions, one dimension of time and three dimensions of space (x, y, z) which are arranged together like four-sided blocks.

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This image of space–time means that time does not exist as past, present and future (Scano 2024; Bhardwaj 2016).

On the other hand, the unit of time is defined by the international system of units based on the electromagnetic wave emitted by the cesium 133 atom (as a result of the electron transition from the excited state to the ground state at zero Kelvin temperature), so that if the electromagnetic wavelength is denoted by  $\lambda$ . For example, the duration of each second is equal to  $9192631770\lambda$  (Verma and Bose 2017). Therefore, it can be claimed that the concept of time relies on the change of mass and energy and takes its validity from the electromagnetic wavelength (mass and energy) (Shamohammadi and Shamohammadi 2024).

In classical physics, time is very important and as a physical tool plays an important role in understanding the natural processes of matter (and energy) interacting with the environment. Time also plays an important role in our daily, monthly and yearly planning. Many models in water (Shahzad et al. 2022), soil (Philip 1957; Mein and Larson 1973; Argyrokastritis and Kerkides 2003 and Shamohama et al. 2013), chemistry such as pseudo–first-order, pseudo-second-order, Elovich models and intraparticle diffusion (Shamohammadi and Shamohammadi 2024) are examples that show that time is important.

In general, even the models written in the fields of hydrology (Soil Conservation Service model method), water and soil (permeation models) and surface chemistry apparently claim to have a theoretical basis, none of them have a strong theoretical basis and are all based on experiments and are experimental (Shamohammadi et al. 2024). For this reason, they generally have defects (sometimes irreparable) (Wang and GUO 2020). Although kinetic models have been widely used, they have at least three basic problems: (1) These models are experimental and lack specific physical meanings, and mass transfer mechanisms cannot be investigated by these models. Also, these models are not able to calculate the maximum absorption capacity, but only able to estimate the equilibrium absorption capacity. The first-order and pseudo-first-order kinetic model (PFO) and the second-order and pseudo-second-order kinetic model (PSO) are important examples of these models. (2) Differential kinetic models, such as external/internal phenomenology and absorption in active site models, have specific physical meanings, but their solution methods are complicated (Wang and GUO 2020). Ho et al. (1999) and Yu W (2020), have claimed that the complexity of problem solving methods prevents the application of these models. (3) In some published articles, kinetic models are inappropriately applied or solved (Wang and GUO 2020). In fact, although the kinetic models are based on the relationship of mass transfer with time, but due to the lack of theoretical foundations, they are generally obtained through experimental methods, as a result, they do not bring satisfactory results (Shamohammadi et al. 2023b).

Despite all the weaknesses of kinetic models, time has been used instead of input mass for many years (Lewis 1937; Horton RE 1940; Philip 1957; Mein and Larson 1973; Argyrokastritis and Kerkides 2003; Shamohammadi et al. 2023b) and this method has been able to meet the needs of knowledge in the field of chemistry, water and soil (Shamohammadi 2024 and Shamohammadi), as if the time–mass equivalence was used based on an unwritten fact, while it has no theory or science (Shamohammadi 2024 and Shamohammadi). Shamohammadi presented the mass time equivalence law (descriptively, not mathematically) and showed that if we change the basis of modeling, both the methods of “using time instead of mass” can be justified and the scientific foundations of modeling are complied. He considers the form of the law of conservation of mass as  $\partial M/\partial t = 0$  to be incomplete and believes that the most important disadvantages of the equation  $\partial M/\partial t = 0$  are: (1) Violation of the model by radioactive materials (materials such as radioactive, even if they are placed in a closed system, they themselves cause the emission of electromagnetic waves, as a result of which the mass changes with time) which causes the violation of  $\partial M/\partial t = 0$ . (2). Models based on the law of conservation of mass as  $\partial M/\partial t = 0$ , such as the Langmuir model (1918), and the Navier–Stokes equation (Shamohammadi et al. 2023a) are only applicable in “perfect equilibrium” conditions. Because such models are written only in closed system, they are never able to present the general mass change curve and do not provide complete mathematical models (Shamohammadi and Shamohammadi 2024).

Shamohammadi (Shamohammadi and Shamohammadi 2024) showed by presenting the law of “dynamic mass” that if the modeling based on the law of conservation of mass is written as  $\partial M_{out}/\partial M_{in} = 1$  (not  $\partial M/\partial t = 0$ ), then we can first He obtained mathematical models of mass–mass and then presented kinetic models by substituting time for mass (the law of equivalence of mass–time).

For the first time in 2016 (Shamohammadi et al. 2022), Shamohammadi presented the adsorption isotherm model based on the equation  $\partial M_{out}/\partial M_{in} = 1$  and claimed that the irreversible reaction takes place before the reversible reaction. Shamohammadi presented irreversibility as a principle. Shamohammadi (Shamohammadi et al. 2023a) presented the retention model and rainfall–runoff model based on the equation  $\partial M_{out}/\partial M_{in} = 1$ . He then used the equation  $\partial M_{out}/\partial M_{in} = 1$  to model water infiltration into the soil and used boundary conditions to build a kinetic model (Shamohammadi et al. 2023b). Shamohammadi showed that, first, the dynamic mass law is applicable to closed systems. Second, when the modeling is written based on the law of dynamic mass, time can be used instead of mass after presenting the model. In equilibrium models, an irreversible reaction takes place before equilibrium.

Shamohammadi (Shamohammadi and Shamohammadi 2024) completed the first law (Law of conservation of mass change) and introduced the second law (equivalence of time–mass) descriptively. He then presented the irreversibility of the reaction (before the reversible reaction) as a law. Shamohammadi et al. (2024) to check the product and reactant curves, in addition to using the unlimited mass flow method in the experiments, they also used the limited mass method in an Erlenmeyer to compare the results, so that the concentration of 200 mg per liter was prepared and poured into Erlenmeyer ( $C_0 = 200\text{mg/L}$ ) and the experiments were performed. They were able to calculate the isotherm model by using the law of conservation of change (although a name for this method has not yet been chosen) and then by subtracting the amount of the product from the total constant mass of  $C_0$ , calculate the amounts of the reactants and finally the curves of the product and the reaction. They drew the donors. Then, using the obtained isotherm model and the third law, kinetic experiments were performed and the absorption kinetic curve was also drawn. They concluded that the dynamic mass equation (variable mass conservation law) both for unlimited flows (Shamohammadi et al. 2023a) and for limited currents are used (Shamohammadi et al. 2024).

On the other hand, based on the information of the World Food and Agriculture Organization (FAO), the area under walnut cultivation in the world is more than 580 thousand hectares and its production is estimated at 700 to 800 thousand tons. In Iran, more than 24 thousand tons of green walnut skins are obtained annually (Munmun et al. 2018). Therefore, removing pollutants such as heavy metals (Fe + 2, Pb + 2, Zn + 2, Ni + 2, Cd + 2, Cu + 2) by walnut shell seems to be one of the economic options. Therefore, to achieve the objectives of the study, green walnut hull (GWH) adsorbents and green walnut hull biochar (GWHB) were used to remove heavy metals (Fe, Pb, Zn, Ni, Cd, Cu). In this case, in addition to expanding the relativity of time in the field of mass (energy), the removal efficiency of heavy metals (Fe, Pb, Zn, Ni, Cd, Cu) from green walnut shell adsorbent (GWH) and green walnut shell biochar (GWHB) should also be investigated (Shamohammadi et al. 2024).

In this research, while developing the basics of equivalence of mass–time to energy domain, by introducing “specific speed of conversion” and “specific time”, a new “general kinetic equation” that is able to estimate the total capacity of the absorber is presented and tested. Also, in this research, “time–mass curvature and mass–mass curvature” are examined and compared with “space–time curvature (general relativity)”.

Therefore, the purpose of this research is: (1) expansion of time relativity in the field of mass and energy (in classical physics), (2) practical use of Shamohammadi laws

in modern modeling, (3) completion and expansion of the theory of time–mass equivalence law in the field of energy, (3) completion and expansion of the theory of “mass time” to the field of energy. (4) Presenting the mathematical equation “equivalence law” of time mass and time energy. (5) Introducing the law of conservation of change and (6) Presenting the general model of kinetics.

In terms of economic value, the new equations that are obtained based on the law of equivalence make (1) the rainfall–runoff equations more accurate, and secondly, by introducing the flood kinetic curve (for the first time), accurate prediction is possible. The peak of the flood will be reached, as a result, irreparable damages that kill thousands of people every year will be prevented. (2) Considering the climate change and water shortage and the weakness of experimental models, the general kinetic model allows for a more accurate estimate of the soil’s capacity to retain water and a lot of savings can be made in the agricultural sector around the world. (3) The matter of economy is very economical due to the equalization of the mass–mass and mass–time (kinetic) equations in organic chemistry and surface chemistry experiments in estimating the capacity of the petrochemical product and the capacity of the adsorbent, and it also avoids wasting time. (4) Half-life equation is theorized based on the law of equivalence and will be more accurate in estimating the half-life of materials (Shamohammadi et al. 2024).

## Definitions and concepts

In this section, all concepts in the field of mass and energy are defined, but in order to obtain a specific result from this research, in the Materials and methods section, we concentrate the definitions and equations for the mass process (in the field of surface absorption).

### Phenomenon

In this study, we use the term phenomenon as a general concept that can include mass, energy, matter, particle or anything that is subject to mass and energy.

Also, throughout this study, we may mention the terms energy, mass, matter, or phenomenon. These names all share one concept, which is that they include mass flow or energy flow or both. The basic difference between the geometry domain and the mass and energy domain (at least in this study) is that in the geometry domain, the goal is to investigate the speed and motion of a particle (Zehe et al. 2001), while in this study we are dealing with the flow. We are faced with mass (transformation of mass into mass or transfer of mass from one medium to another) and energy flow (transformation of energy into energy).

## The changing world (phenomenon)

So far, we have not read any scientific report in which he talked about the constant and unchanging world, one of the reasons for the existence of the changing world is the existence of all kinds of formulas, models and equations in different fields of knowledge and at different levels of physics (classical, relativistic and quantum) is from the equations written in the cosmological field, including the constant expansion of the universe, the birth and death of stars, and the absorption of celestial bodies by black holes (Gorkavyy and Tyul'bashev 2021) to numerous equations that are used in various fields of biology, chemistry, and classical physics. And it is written under the atoms, all of them are the reason for the existence of change in various world phenomena. For example, when it is said in mathematics:  $y = x^2$ , it means that  $x$  is variable and  $y$  is also a function of  $x$ , as a result  $y$  is also variable. Obviously, when it comes to changing the world, the change is in natural conditions, not artificial and laboratory conditions. Therefore, the world as a phenomenon (which itself has infinite phenomena) is the essence of change. This has been going on since the big bang until now (Shamohammadi and Shamihammadi 2024).

Also, the de Broglie wave theory, which has been confirmed today, shows that all materials in nature have particle wave duality (Butto 2020; Chauhan et al. 2013). This theory alone confirms the continuous change in the phenomena of the world. On the other hand, basically the most fundamental sub-atomic particles also all inherently have spin, which means that they always have angular momentum and are constantly moving and changing mass and energy (Rose 2023).

Therefore, we can say so far: the premise of making various scientific equations in the world is "change". But the basic question is, do all the components of nature have a constant "rate of change" in the interaction with their surrounding environment? Do global phenomena only change in one direction? The answer, of course, is negative to both questions. The erosion rate of stone is not the same as the erosion rate of wood and metal. Also, the rate of water infiltration in the soil is not the same as the growth rate of the sunflower plant or the production rate of nitrogen dioxide from dinitrogen tetraoxide and the rate of formation of dwarf stars. Even depending on which angle we look at the interactions of matter, the rate of change of a phenomenon from different directions is not necessarily the same. For example, a piece of rock erodes, absorbs surrounding dust particles as surface absorption, and moves in space based on cosmic expansion. In such a case, it cannot be said that the rate of stone changes in different subjects is necessarily the same. Also, the rate of rock erosion changes with the increase in the amount of erosion (based on the half-life equation). This change is also done in the case of stone movement in space

and surface absorption on it. These changes will be different in different environmental conditions. For example, surface absorption, which is one of the indicators of change, changes with increasing temperature (Langmuir 1918; Shamohammadi et al. 2022) and the rate of kinetic absorption increases with temperature (Ho et al. 1999).

When space time is said in the theory of space time, space time is a set of four-sided blocks (Bhardwaj 2016), which means that the coordinates ( $x$ ,  $y$ ,  $z$  and  $t$ ) of each block are different from each other, and this means a change in space. Otherwise, it was said that space time has a single block. This issue is related to the geometry of space and has nothing to do with the continuous change of the particle (particle wave property and particle spin property). In other words, the particle in space can have various changes from different directions.

So, in addition to the change in the mass and energy of a particle through its movement and speed (in relativistic physics), the change in its mass and energy is also done through the conversion of mass into energy (or energy into mass). As a result, the change in the displacement of a particle (phenomenon) and the change in the mass and energy conversion of the same particle can be done together, while it is possible that their rate of change is not the same. For example, a photon of light is changing both due to movement in space (geometric displacement) and due to conversion of mass into energy (and conversion of energy into mass) by electromagnetic waves (Winter et al. 2017a; Lecca 2021). That is, it is possible to check the change in a light particle from at least two angles (perhaps we can also talk about  $n$  dimensions of change). This is also true about plants, animals, etc. So the world is a collection of phenomena that are always changing, as if the phenomena themselves are equivalent to change. In other words, if we call the phenomenon equivalent or equivalent to change, we have not said a wrong word. Because the phenomenon is always changing in interaction with its surrounding environment. So we think, the "equivalent" phenomenon is change. In other words, change in any phenomenon is inherent in the interaction with the surrounding environment (open system). Otherwise, the name of the phenomenon cannot be put on it.

With this explanation, we can say:

The first theory: Any phenomenon, no matter how it is said or written (mass, energy, matter, particle), is equivalent to "change". Therefore, considering that the phenomenon has mass and energy, as a result corresponding to the law of conservation of mass and energy, the law of conservation of "change of mass" and the law of conservation of "change of energy" can also be presented. Law of survival of change: Change is neither created nor destroyed, but changes from one state to another. The law of survival of change can be expressed in different ways. For example, if an initial variable substance is transformed into several other variable

substances, the initial mass change is equal to the sum of the changes in the partial masses of the system. This issue is also true for energy (Shamohammadi et al. 2024; Shamohammadi and Shamohammadi 2024). Also, it can be said: in a process of transformation or change (with or without change of nature), the rate of change of the components of the phenomenon is equal to 1 in total (see the first law in this article). We think that the law of conservation of change precedes the law of conservation of mass-energy. Because in theories such as the theory of the spontaneous creation of the world *Ex Nihilo* (Lincoln and Wasser 2013) that the world was created from nothing, what remains constant is the change itself, not mass and energy.

## Time

In this part, we start to examine the concept of time from the definition of the International Units (SI) and International Quantities (ISQ).

### Standard time

Definition: Based on the definition of International Units (SI),  $1(\text{s}) = 9192631770\lambda(\text{m})$ .  $\lambda$  is the electromagnetic wavelength emitted by the cesium 133 atom at zero Kelvin temperature under special conditions of special global stations (Shamohammadi and Shamohammadi 2024).

But based on Dobroy's equation (Butto 2020), the value of  $\lambda$  is obtained from the following equation.

$$\lambda = \frac{h}{m_0 v} = \frac{h}{mv \sqrt{1 - \frac{v^2}{c^2}}} \quad (1)$$

Planck's constant  $h$  is equal  $6.62607015 * 10^{-34}$  J.s.  $m$  is the mass in motion,  $m_0$  is the mass at rest (kg),  $m_0$  is the mass at rest (kg),  $v$  velocity of moving mass and  $c$  is the speed of light (m/s). The unit  $\lambda$  was defined earlier (meter).

And according to Eq. 1, one second is equal to the amounts of mass and energy that are changing through the cesium 133 atom in certain conditions. So that if the electrons of the cesium atom are not excited and do not return to the basic levels, or in mathematical terms, the created wavelength tends to zero ( $\lambda \rightarrow 0$ ), the time of one second will also tend to zero ( $t \rightarrow 0$ ). On the other hand, if the wavelength of the cesium atom tends to infinity,  $\lambda \rightarrow \infty$ , the time of one second also tends to infinity, as if the time has stretched. Probably, this happens in a black hole, because according to Eq. 1, in the natural state of the phenomenon, there is no stationary state where the velocity becomes zero (Butto 2020), so the wavelength will not be infinite. Now suppose another atom other than cesium atom is used for standard time, in this case the definition of second will also be different due to the difference in the emitted wavelength. Therefore, the

cesium 133 atom has a special time, depending on different conditions, its value is proportional to the change in the value of  $\lambda$ . As in general relativity, every particle (in motion) has a special time and time changes in different points of space, so that it is always stationary relative to that particle. In this case, just like a particle in space-time, whose specific time changes according to the distance of the particle to the center of gravity, for the cesium atom, the value of  $\lambda$  will change with the change of environmental conditions, such as increasing temperature and proximity to the center of gravity. In this case, the specific time of Cesium 133 atom will change according to the change of  $\lambda$  and as a result of the change of mass and energy. As a result, time in the field of physics is nothing but change depending on the change of phenomenon. So the value "9192631770 $\lambda$ " is a standardized specific time for a cesium-133 atom, named in units of seconds.

This issue can be generalized for any material or any other system. For example, rock erosion also experiences a rate of change that produces its own special time. But because every phenomenon has its own time, scientists decided to choose a universal unit for time that is equal to  $9192631770\lambda$  under certain conditions (zero Kelvin temperature) and on earth, which we call standard specific time.

Based on the above concepts, this unit of time is like a universal time line, which is used as an accepted standard to measure the movement and changes in the world. In other words, time measured at special global stations is assumed to be a straight line without bending (Winter et al. 2017a; Lecca 2021). In fact, keeping the environmental conditions constant, the produced time is shown as a straight line, without bending. But if the same cesium atom changes its location or the temperature conditions of its environment change, the time produced by the cesium atom will no longer be a straight universal line. As a result, the cesium 133 atom itself has a curved time line compared to the time measured by the cesium 133 atom in the special global station. This issue can be generalized about space and light. As we know, the speed of light bends near the center of gravity and its speed slows down, as a result, according to Eq. 1, the bending of the speed of light (slowing down of the speed of light) affects  $\lambda$  and subsequently affects the specific time of photons. For this reason, the bending of time is proposed in general relativity. Because time (in the field of physics) is nothing but the change of mass and energy (Winter et al. 2017a; Lecca 2021). For this reason, when space (mass and energy) is bent or light (mass and energy) is bent, their rate of change slows down, as a result, time (which is equivalent to the change of mass and energy) is also bent and slow brings cash) becomes.

In the theory of general relativity, in fact, the three dimensions of space ( $x, y, z$ ) that make up the geometric dimensions of a particle are a package of energy mass whose

specific time is  $t$ , and Einstein called it the fourth dimension of space time, or rather specific time, called a particle (with coordinates  $x, y, z$ ) (Nickerson et al. 2004). In fact, a change in the spatial dimensions of a particle causes a change in special time or the fourth dimension (just like the inherent change of the cesium atom that leads to the production of time).

But as mentioned in the first theory, every phenomenon is inherently variable. For this reason, the particle in general relativity is equivalent to change. Because it changes at least in two directions, both due to cosmic expansion and due to the presence of gravity centers. In this case, its specific time (fourth dimension) is also variable (Pyykko 2012; Gillespie 1977; Nickerson et al. 2004; Winter et al. 2017a; Lecca 2021; Michaletti et al. 2017) (Reminder: in terms of general relativity, only the geometrical changes of the particle are examined, that is, only one of the changes of the phenomenon). But the point that needs to be pointed out is that to measure the specific time, the time that the observer measures is used (conditions that are fixed and different from the target particle), as a result of the “mass package of the particle’s energy” and as a result “Its special time” is not shown as a straight line, but as a curve relative to the time of the local observer. If for a moving particle, the relationship between its specific time dimension and the three dimensions of space (the result of the three dimensions of space  $x, y, z$ ) is always a straight line with an angle of 45. In fact, the dimension of special time always coincides with the result of the dimensions of space, but both time and space are bent with respect to the time of the local observer (due to the constant and different conditions of that local clock). Or better to say, space time has a curvature relative to the local observer.

The second theory: time, whether it is standard or special, or the time of the local observer, in any way it is expressed, has one meaning, and that is that “time” is equivalent to “change”.

The general result of this part: the phenomenon in any form expressed (mass, energy, particle, etc.), is equivalent to “change”. Also, “time” is equivalent to “change” in any way it is defined. As a result, it can be said: “phenomenon” is equivalent to “time” no matter how it is defined (Fig. 1).

Based on Fig. 1, it can be said that the lifespan of people who are more active in sports or dancers who are more active on the stage is shorter, because when the actions and reactions in a happy event, such as a concert, are increased, the change in energy increases, as a result, their special time passes faster and affects people’s age as well. This issue is completely consistent with the results of the research that shows that athletes and performers (singers) have a shorter lifespan than professors and religious and academic figures (Thieme and Fröhlich 2020).

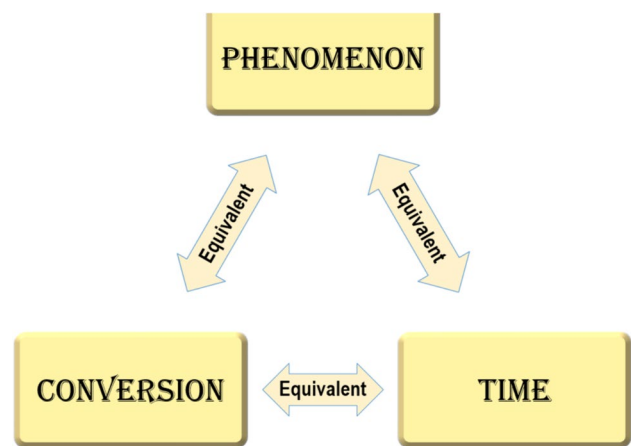


Fig. 1 The relationship between phenomenon, time and change

Figure 1 can also solve the challenge of whether or not there is time, because if we call change itself time, time exists, but if we consider time dependent on change in the phenomenon (which is the case in our opinion), time does not (It does not exist independently). On the other hand, time has no direction, just as the value of  $\lambda$  is not directional in the definition of standard time. This issue is also observed in all mathematical and physics equations (Shamohammadi et al. 2024). One of the reasons that time believers claim for the existence of time is its directionality. Their reason is that according to the second law of thermodynamics (a law which itself is timeless), the world moves toward disorder (increasing entropy). But they have forgotten that we have a knowledge called the knowledge of surface absorption, which is part of the science of chemistry (Shamohammadi et al. 2024). Also, attraction of phenomena by gravity centers in space-time, including black holes. All these are aimed at reducing entropy and reducing disorder. The law of the survival of change as a fundamental law also does not dictate a specific direction, because every change inherently has precedence and delay, so the past, present and future find meaning in it. Considering that “change” causes the equivalence of the phenomenon of time (equivalence of mass-energy-time), it can be claimed that the “law of conservation of change” is not only earlier than the law of conservation of mass-energy, but also more fundamental than It is also because it is the factor of connection, unity and conversion of mass, energy and time to each other. Therefore, it seems that all the fundamental concepts of physics, but also the fundamental concepts of the world, are based on change and the law of survival of change. One of the reasons for this claim is its application and impact on modern modeling (Shamohammadi et al. 2022; Shamohammadi et al. 2023a, b; Shamohammadi and Shamohammadi 2024; Shamohammadi et al. 2024).

**Use of time**

As mentioned, time is equivalent to change, but according to international agreement and agreement, units are defined for it to show “change” quantitatively and standardly. Therefore, in addition to being the equivalent of “change”, time is also a measuring tool of “change”. For example, you can make a watch by turning a plastic ring around your finger (finger-ring system). In this way, the energy of the finger plays the role of a battery, and one round of the ring around the finger plays the role of the unit of measurement, and the process of rotating the ring causes change and energy consumption, and by changing the energy, it produces time. Now the speed of two cars (number 1 and 2) can be calculated and compared with it. In this case, it can be said that car number one has traveled 10 m per “round of the ring”, and car number two has traveled 15 m per “round of the ring”.

**Specific conversion speed (*v*)**

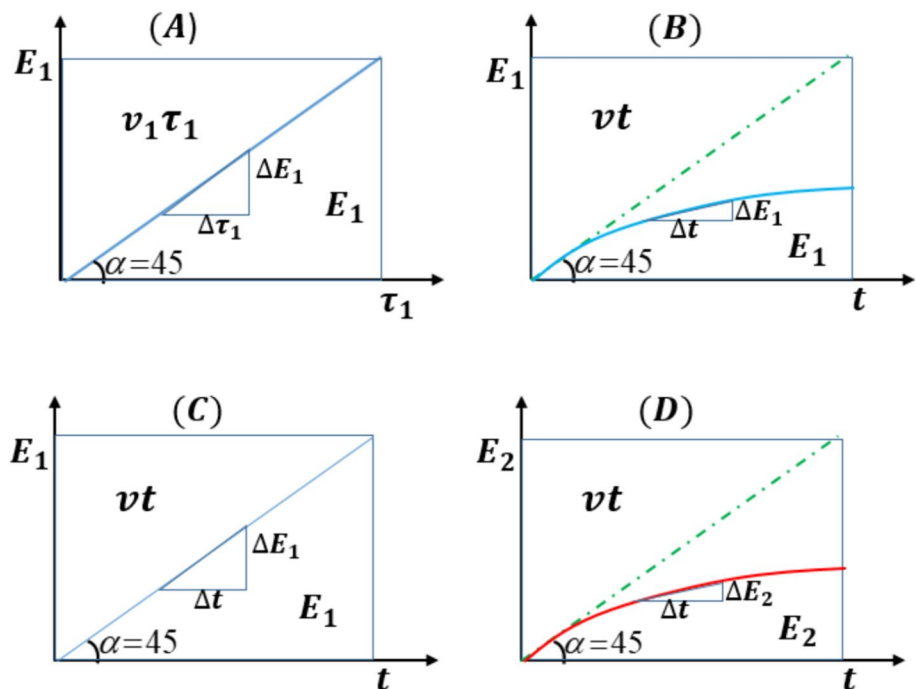
In the example above, the specific time ( $\tau$ ) can be explained as follows: In the finger-ring system, suppose we call each round of the ring a unit of time, and suppose that at the beginning the round of the ring is fast, but then it gradually slows down and becomes slower. In this case, a specific time curve  $\tau_1$  corresponding to the system energy change curve ( $E_1$ ) is created (Fig. 2a). This curve for finger energy changes and its specific time ( $\tau_1$ ) is a line with an angle of  $45^\circ$ , because with the increase of energy, the

number of revolutions of the ring becomes faster and with the decrease of energy, the number of revolutions of the ring becomes slower. As a result, the slope of the line or the specific rate of change of the system is always equal to 1 (Shamohammadi and Shamohammad 2024). In other words, if we assume that the unit of energy is Joule and the unit of specific time is second, according to Fig. 2a, we can always write  $v_1 = \frac{\Delta E_1}{\Delta \tau_1} = 1 \text{ J/s}$ . As a result, by defining the specific speed for mass flow or energy flow, in a system where the value of  $E_1$  is converted to  $E_2$  (for example, suppose  $E_2$  can be the heat resulting from the finger-ring system), instead of using the energy time equivalence (or mass time), the equation of equality was used as  $E_1 = v_1 \tau_1 \hookrightarrow E_2 = v_2 \tau_2$ .

Now, we must note, in normal conditions, the specific speed, which is a straight line with an angle of  $45^\circ$  to the specific time, will be curved with respect to the local time ( $t$ ) (Fig. 2b), but if the input energy conditions ( $E_1$ ) are measured uniformly and controlled by local time,  $E_1$  energy will also be a straight line with respect to local time. Meanwhile, the output energy curve of the  $E_2$  system relative to local time will not necessarily be a straight line with an angle of  $45^\circ$ .

In short, it can be said: conversion in a mass (energy) flow, specific speed is the ratio of the changes of the phenomenon to the changes of its specific time. In experiments, we usually consider the flow of mass (energy) to be uniform with respect to local time, then the system gives us the output results. In this case, instead of the relation  $E_1 = v_1 \tau_1$ , the relation  $E_1 = v_1 t_1$  can be used. Here the value of  $v_1$  will be at

**Fig. 2** Specific speed of mass (energy) flow in figures a and b in natural conditions and figures c and d in laboratory conditions



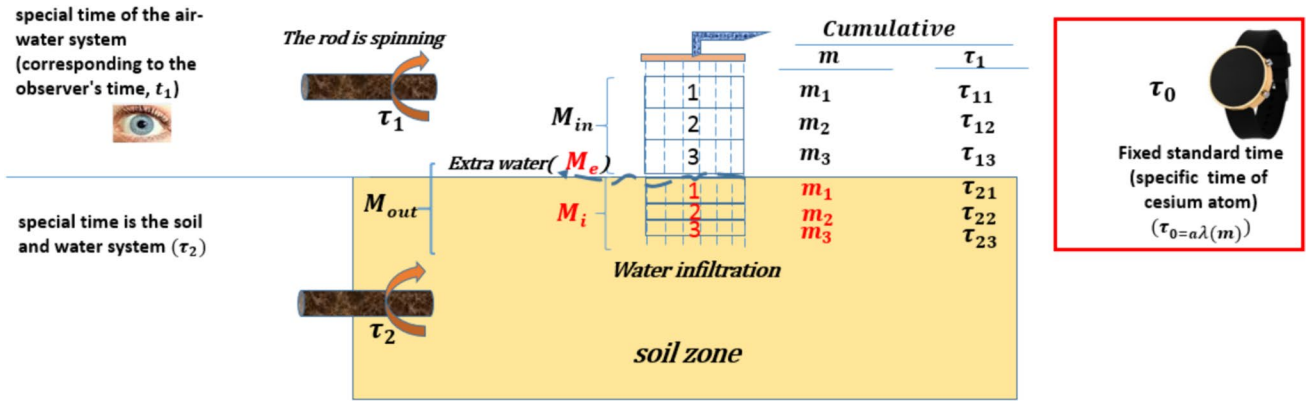


Fig. 3 specific time of water flow in air and soil environments

most 1. If the curve  $E_2 = v_2 t_2$  is not necessarily a line with an angle of  $45^\circ$  relative to the time of the local observer, it can be bent.

Obviously, the unit of specific speed is obtained based on the units of measurement. For example, if the studied quantity is in mg/liter, its rate is  $v(mgL^{-1}/s)$  and if the time is in minutes, its rate is  $v(mgL^{-1}/min)$ . This is about the parameters that are measured in centimeters (depth of water penetration); its rate will be  $v(cm/s)$  in relation to its specific time. We call the name  $v$  the specific speed of transformation, its absolute value is at most equal to 1 (see Fig. 2), and its dimension will be different depending on the studied variable. In fact,  $v$  corresponds to the speed of light ( $c$ ) used in the energy–mass equivalence equation. The maximum speed of light ( $c$ ) is 299,792,458 m/s, but it may decrease in different environments.

To better understand the equivalence, we use the process of water infiltration into the soil as an example. Processes can be quantitative (physical) or qualitative (chemical reactions), but we use the example of water penetration into the soil so that it can be touched and understood.

Figure 3 (left) shows the specific time for a rod in two systems, one air and the other soil. Correspondingly, the water flow is carried out uniformly on the soil by a sprinkler (assuming the end of the soil column is closed). The position of local observer time and international standard time are also seen in the figure.

In step (1) suppose the rod rotates in the air with a constant energy. Imagine that the bar could be a clock where the battery power behind the clock makes the clock hands rotate. According to the definition, its specific time is equal to  $\tau_1$  and  $\tau_1$  is equal (equivalent) to the rotation (mass and energy change) of the rod. Now let us suppose we put the same rod in the soil and rotate it with the same initial energy; in this case, its specific time is equal to  $\tau_2$ . We all know based on experience that for an equal energy, the number of revolutions of the rod in the first state ( $\tau_1$ ) is more than the number

of revolutions in the second state ( $\tau_2$ ). In other words, the specific time of the rod in the soil increases relative to the air (time dilation). This issue also happens when comparing the flow of water in the air with its flow in the soil, with the difference that as the water flow continues in the soil, any desired part of the water will have its own special time, but in total, the water in Soil infiltrates,  $M_i$  (energy loss in both systems is zero due to low velocity), slower than water flowing through air,  $M_{in}$ . On the other hand, the noteworthy point is that as the penetration of water slows down in the soil, the same amount of water returns to the original medium (air),  $M_e$ , and flows on the soil surface as additional water, so that according to the mass conservation law, it can always be written:  $M_e + M_i M_{in} = M_{out} = M_e + M_i M_{in} = M_{out} =$ . Obviously, with the reduction of water infiltration into the soil,  $M_i$ , the amount of excess water,  $M_e$ , increases.

Figure 4 shows the mathematical relationships between the variables in Fig. 3. As can be seen, figures a, b, and c, respectively, show a linear relationship (with an angle of  $45^\circ$ ) between  $M_{in}$  (mass–air system) and its specific time, between  $M_i$  (mass–soil system) and its specific time, and between  $M_e$  (It shows the mass–air system) and its specific time. Figure d also shows that the relationship between the input mass and the output mass is a line with an angle of  $45^\circ$  according to the law of stability, the figures e, f and g show the bending of the mass—the mass and the time—mass penetrate between the water mass and the input mass—respectively. It shows the penetrated mass, specific time—penetrated mass and observer time—penetrated mass. The reason for that is completely understandable because according to Fig. 3, the flow of water in the air enters the earth’s surface uniformly and in equal blocks, but inside the soil, when the soil is dry, the infiltration rate is equal to the rate of incoming water (Shamohammadi et al. 2023b), but gradually as the soil becomes saturated, the amount of infiltration becomes less and less, so that at the end of the experiment, we will no



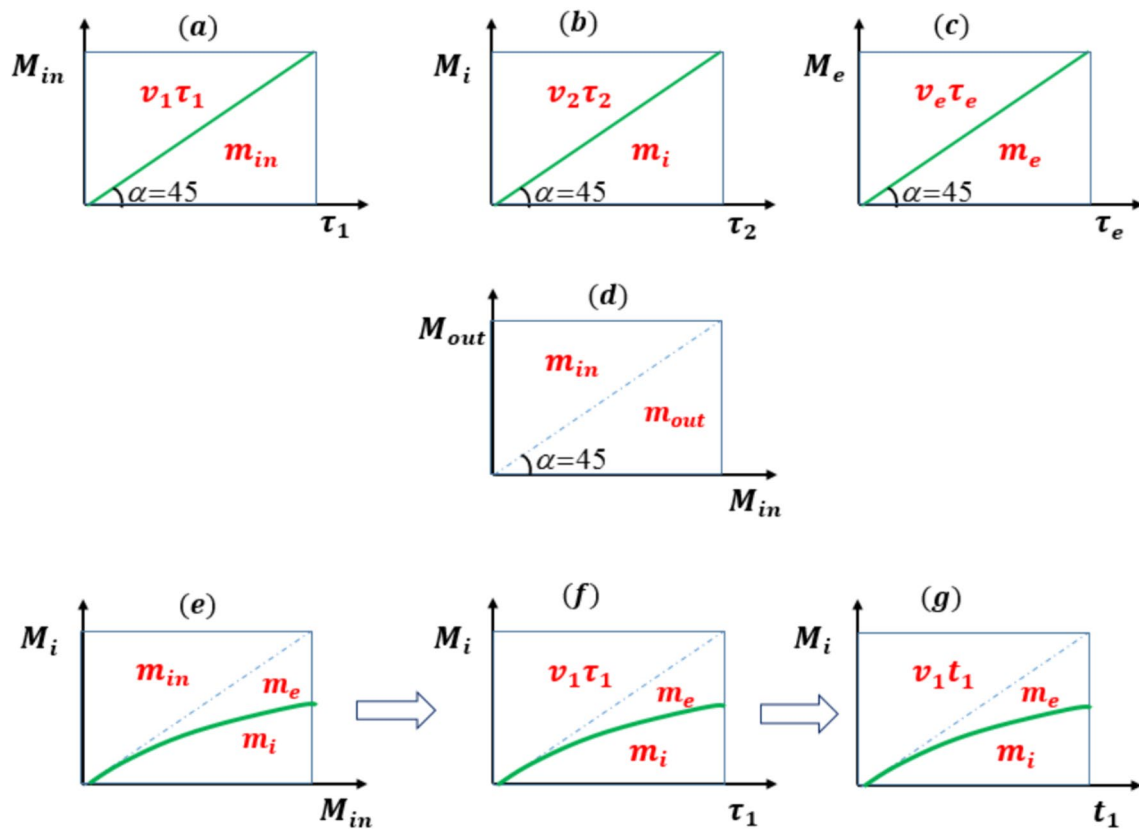


Fig. 4 Relativity of time in the slow transfer of water mass from the air to the soil

longer have water infiltration and all the water will leave as surface flow (excess water) (Shamohammadi et al. 2023b).

On the other hand, as mentioned earlier, based on the theory of general relativity, the specific time of each system is stationary relative to the changes of the same system (Fig. 4a, b, and c). On the other hand, in Fig. 4a,  $M_{in} \equiv \tau_1$ . As a result of any relationship between  $M_i$  and  $M_{in}$  (Fig. 4e), the same relationship will be established between  $M_i$  and  $\tau_1$  (Fig. 4a). Therefore, figure 4-f is also obtained based on Fig. 4a and e.

The relationship between mass and time has been established experimentally and in different scientific fields in the form of kinetic models for years, and equivalence has also been carried out (Wang and Guo 2020; Philip 1957; Mein and Larson 1973; Argyrokastritis and Kerkides 2003; Shamohammadi et al. 2023b), but it had no scientific and theoretical basis. Shamohammadi (Shamohammadi and Shamohammadi 2024) was able to present the mass–time equivalence law with a simple example and by referring to valid references, but still the void of stronger theoretical foundations was felt in that study. Therefore, according to the definitions of specific time, specific speed, relations of mass–time parameters (Fig. 4) and given explanations, the theory of the law of “equivalence of mass–time” is completed.

Here, the difference between time relativity in “space–time” (Alley 1979; Verma and Bose 2017) and time relativity in “mass–energy (classical physics)” is summarized as follows:

In general, we do not see any difference between the basics of general relativity and relativity in the field of classical physics, but 3 points are important:

According to Einstein’s opinion, time is one of the 4 dimensions of space, and there is a special time for every particle in space, while in the field of mass and energy, there is a special time for every phenomenon in the number of physical, chemical and biological changes of that phenomenon. As a result, it can be said that for a phenomenon, there is a special time for the number of changes that the phenomenon has in different physical, chemical and biological directions.

Although Einstein considers time to be an illusion, he mentions time as if it is a phenomenon independent of mass and energy and independent of space. We believe that time relies on the change of phenomena. Therefore, time is “equivalent” to “change” of the phenomenon. As a result, it is also the currency of space. According to our definition, space and particles in space (such as light) are all phenomena, therefore they are equivalent to change and equivalent to

time. In addition, our subject is not specific to space (movement and speed of particles), but wherever there is a flow of mass and energy, there will be an equivalence of time.

In general relativity, Einstein used the speed of light  $c$  to solve the equations and it is everywhere in m/s, while we use  $v$ , which is called the special rate (or special rate of change) and is changing for any phenomenon. Its dimension is different, but its value is equal to 1 for the same phenomenon.

## Introducing new modeling rules in the field of classical physics

### (1) First law

Law of conservation of mass change: In a mass process (with or without change in nature), the total mass rate of the components is equal to 1 (Shamohammadi and Shamohammadi 2024). For example, in a mass system, when the mass  $M$  is converted into components  $\partial m_1, \partial m_2, \partial m_3$  (Eq. 1), based on the law of conservation of mass, the dynamic mass equation is written as Eq. 2. Because according to the law of conservation of mass (dynamic mass), in a system it is always possible to write:  $\partial M_{in} = \partial M_{out}$ , as a result, when the mass  $\partial M_{in}$  turns into three components  $\partial m_1, \partial m_2, \partial m_3$  (Shamohammadi and Shamohammadi 2024), the law of conservation of dynamic mass can be written as follows:

$$\begin{aligned} \partial M_{in} &= \partial M_{out} \\ \partial M_{in} &= \partial m_1 + \partial m_2 + \partial m_3 \end{aligned} \quad (2)$$

Because the dynamic (variable) mass derivative is not zero, by dividing the sides by  $\partial M_{in}$ , the result is obtained as Eq. 3.

$$\frac{\partial M_{out}}{\partial M_{in}} = \frac{\partial m_1}{\partial M_{in}} + \frac{\partial m_2}{\partial M_{in}} + \frac{\partial m_3}{\partial M_{in}} + \dots = 1 \rightarrow \sum_0^n \frac{\partial m_i}{\partial M_{in}} = 1 \quad (3)$$

This law is the same for energy flow as for mass flow (Shamohammadi and Shamohammadi 2024). Therefore, if one or more energies ( $E_{in}$ ) are converted into one or more energies ( $e_i$ ), based on the law of conservation of variable energy, it can be written.

Equation 4 is the law of conservation of energy change.

$$\frac{\partial E_{out}}{\partial E_{in}} = \frac{\partial e_1}{\partial E_{in}} + \frac{\partial e_2}{\partial E_{in}} + \frac{\partial e_3}{\partial E_{in}} + \dots = 1 \rightarrow \sum_0^n \frac{\partial e_i}{\partial E_{in}} = 1 \quad (4)$$

The first law can also be introduced as the law of conservation of mass-energy change. To understand the importance of the first law, we will discuss a little about the law of conservation of mass. Currently, the mathematical form of the law of conservation of mass is used as  $d(M)/dt=0$

(for macroscopic mass flow in chemistry). As mentioned earlier, this form of survival law, in addition to being unable to explain the conversion of radioactive material into energy (Shamohammadi et al. 2024), is also unable to explain changes in the chemical kinetic curve. In other words, it is only able to calculate instantaneous speed. The interesting thing here is that the application of this law ( $dM/dt=0$ ) is only limited to the equilibrium point of the kinetic curves and the most important result it gives us is: forward speed = return speed. Meanwhile, at the point of chemical equilibrium, the speed of movement and the speed of return of substances in macroscopic conditions are both zero. A strange fallacy is made here. This fallacy is that the conservation law ( $dM/dt=0$ ) is written for macroscopic flow, but the result obtained from it is related to the microscopic behavior of matter. The conservation law is usually written as follows. The more important issue is that using the law of conservation of mass as  $d(M)/dt=0$  will never lead to the construction of a kinetic mathematical model, because the sum of the amounts of dissolved substances is always zero in all reaction stages (not only in the equilibrium state):  $[A]+[B]=0$ . The main reason for this weakness is that the law of conservation of mass looks at the system from the outside. In this case, the total mass is always evaluated and because the total mass is constant from the outside, as a result, the real changes of the initial mass process are not seen, while the chemical kinetic curves are a convincing reason to tell us, the mass flow exists between the reactants and the product within the system. The main difference between the law of conservation of change (mass) and the law of conservation of mass is that in the law of conservation of change, it examines the system as it is, and we do not have to consider the system hypothetically and assume it is closed. This issue lies in the nature of the law.

$$\begin{aligned} \frac{d(M)}{dt} = 0 &\rightarrow \frac{d([A] + [B])}{dt} = 0 \rightarrow \frac{d[A]}{dt} \\ &+ \frac{d[B]}{dt} = 0 \rightarrow -\frac{d[A]}{dt} = \frac{d[B]}{dt} \end{aligned}$$

The truth is that the systems are basically open, but whenever we don't have information about the input and output of the system, we assume it as a closed system with a hypothetical line to solve the problem more easily. In other words, we look at the system from the outside. In the application of the law of survival of change, systems are always examined in an open manner (looking from the inside). For example, in an Erlenmeyer, when material A is converted to material B, to check the mass flow,  $dA$ , which is a part of the total mass of A, is input and  $dB$  is output. This issue can be continued until the last particle (because there is mass flow during the reactions). The only difference between mass flow in limited environments such as Erlenmeyer compared to unlimited environments such as water flow in a river or water

infiltration into the soil is that the amount of matter in Erlenmeyer is limited. This issue becomes important when we want to draw the curve of reactants. To calculate the amount of reactants in Erlenmeyer, we subtract the amount of the product from the total amount of the substance, which is constant, while in unlimited flows, we consider the amount of the total substance to be variable and subtract the amount of reactants from the variable substance. This is the reason why so far more than ten mathematical models have been written in limited flows (field of organic chemistry) and unlimited flows (field of surface chemistry, water, soil, hydrology and motion physics) (Shamihammadi et al. 2022; Shamihammadi et al. 2023a; Shamihammadi et al. 2024). Therefore, the application of the first law is possible for all environments, and this is the unique feature of the law of survival of change. If using the form  $\sum_0^n \frac{\partial m_i}{\partial M_{in}} = 1$ , in addition to not violating the law of constancy (because it is not dependent on time), it includes the entire process curve of mass (or energy) and It can be used in open systems (Shamohammadi et al. 2023b), most importantly, it is the basic basis of the equivalence law of mass time or energy time (Shamohammadi et al. 2024).

(2) Second law

The law of irreversibility: “In equilibrium systems in which mass (Energy) processes are carried out, an irreversible reaction takes place before the reversibility stage”. In other words, in equilibrium curves, when the independent variable tends to zero, the asymptote of the curve is a line with an angle of 45° that is tangent to the curve (Shamohammadi et al. 2024).

(3) Third law

Therefore, according to the above explanations, the law of equivalence can be defined as follows:

$$m \equiv t \rightarrow m = \left( \frac{\Delta M_{out}}{\Delta t} \right) t = vt$$

And simply, the law of equivalence is:

$$M = vt \tag{I}$$

v is at most equal to 1.

Equivalence law (third law) can also be written as  $\sum_0^n \frac{\partial m_i}{\partial (v_{in} t_{in})} = 1$ , based on the first law. The simplified form of the mathematical equation of the time–mass equivalence law is as follows.

In the law of equivalence of mass–time, the behavior pattern of mass (variable) and time is similar, but the values of mass and time are not necessarily equal.

The third law is also true about energy (Shamohammadi and Shamohammadi 2024), namely:  $\sum_0^n \frac{\partial m_i}{\partial (v_{in} t_{in})} = 1$ .

As a result, the energytime equivalence law can be simply written as  $E = vt$ . The law of equivalence of time–mass and energytime is similar to the equations of motion of a particle in the mechanics of motion. Therefore, the energytime equivalence law is also written as equation (II).

$$E = vt \tag{II}$$

Therefore, the general form of mass and energy balance models can be written based on the first law and the second law, in the conditions of a closed system for mass (Fig. 1a) and energy (Fig. 1b), and then based on the law “equivalence” it showed the general kinetic models for mass (Fig. 1c) and energy (Fig. 1d) in Fig. 1.

As can be seen in Fig. 5, all equilibrium curves are placed between the two lines L1 (the bisector of the coordinate axis) and L2, the line parallel to the horizon axis. Studies by Shamohammadi et al.(2022), Shamohammadi et al. (2023a), Shamohammadi et al.(2023b), Shamohammadi and Shamohammadi (2024), Shamohammadi et al.(2024), Nimibofa et al.(2017), Sahu et al. (2013), Langmuir (1918), Alafnan et al. (2021), Lagergren(1898), Ho et al. (1999) confirm Fig. 5. As mentioned before, the first rule can be used in open systems (Shamohammadi et al. 2023a, 2023b), so according to the format of the second and third rules, it can be said that they are in open and semi-open systems. They can also be used.

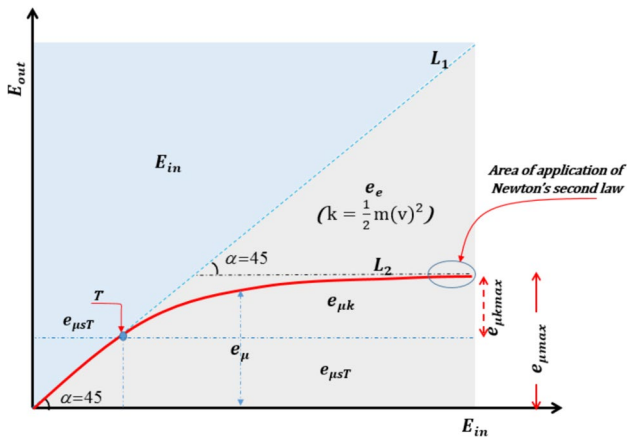
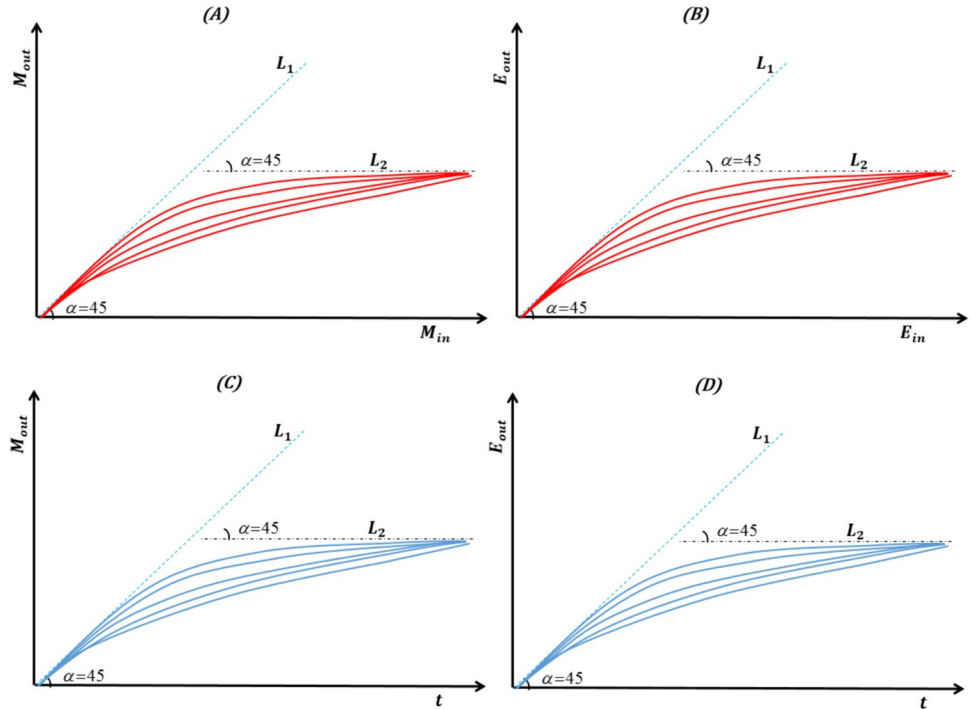
Here we get two examples of mathematical models based on equilibrium systems: (1) the equation of body movement (energy flow) and (2) the equation of surface absorption of materials by the absorber (mass flow) (3) Materials and methods.

(1) The equation of motion of the body based on energy flow

The equation of motion of an object that moves from rest using the energy input to the system ( $E_{in}$ ) and finally reaches the equilibrium condition (the result of the forces acting on the object is zero) is derived as follows and that using the conceptual equations of the form 5 is obtained.

Figure 6 shows the conceptual curve of the movement of the object on the surface of the earth and the energy exchange process. The amount of energy that is spent to move the object from a stationary state to a moving state and then with a gradual increase in energy causes the object to move at a constant speed is shown in Fig. 6.

**Fig. 5** General form of equilibrium curves in the field of mass and energy in classical physics, equilibrium system, **a** mass–mass, **b** energy–energy, **c** mass–time and **d** energy–time



**Fig. 6** The overall movement curve of the object (from rest to equilibrium motion) based on input energy

$E_{in}$  parameters: total energy transferred to the object.  $E_{out}$ : the output energy of the system, including the energy used to overcome friction and the kinetic energy of the moving object. Kinetic energy or reversible equilibrium energy ( $e_e$ ) returns to the environment.  $e_e$ : reversible equilibrium energy (kinetic energy of the object).  $e_{\mu sT}$ : the maximum energy that is required to overcome friction in a state of rest so that the object is on the threshold of movement (energy consumed at the threshold of dynamic equilibrium point).  $e_{\mu k}$ : the energy that is spent on the friction of the body-earth system while moving. Threshold point of dynamic equilibrium is the beginning of the equilibrium part of the energy and the

beginning of the movement of the object. Until the threshold of dynamic equilibrium, the total input energy is used to increase the internal energy of the system ( $e_{\mu sT}$ ). The value of  $e_{\mu sT}$  is a fixed number. The sum of  $e_{\mu k}$  and  $e_{\mu sT}$  is equal to the friction energy of the whole system and is denoted by the symbol  $e_{\mu}$ . The value of  $e_{\mu}$  can also include air resistance, but it is ignored in normal speeds. Figure 7 shows the equilibrium portion of the energy of motion, the irreversible energy portion (second law) or  $e_{\mu sT}$  is separated from the motion curve to obtain the equation for the reversible portion of the energy. In this case, the energy entered before movement is added to the equation as a constant value.

As mentioned, the value of  $e_e$  is the kinetic energy of the body, which can also be written as Eq. 4. Kinetic energy returns to the system through the movement of the body.

$$e_e = k = \frac{1}{2}m(v)^2 \tag{5}$$

For modeling, using the curve in Fig. 7, the energy conservation law for the equilibrium part (variable part of the curve) can be written as follows:

$$E_{in} - e_{\mu sT} = e_e + e_{\mu k} \tag{6}$$

And if  $E_1$  (residual energy) is used instead of  $E_{in} - e_{\mu sT}$ , then by deriving Eq. 5 Eq. 6 is obtained.

$$dE_1 = de_e + de_{\mu k} \tag{7}$$

By dividing the sides by  $dE_1$ , we will have

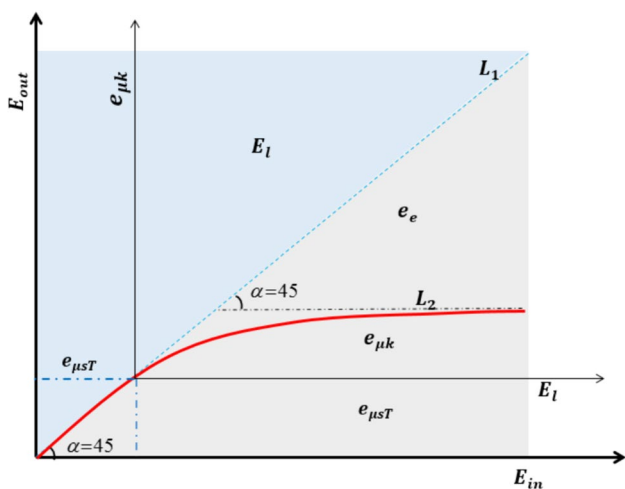


Fig. 7 Separating the part of absorbed energy (non-equilibrium) from the equilibrium energy of the system

$$1 = \frac{de_e}{dE_l} + \frac{de_{\mu k}}{dE_l} \tag{8}$$

Equation 7 is Shamohammadi’s first law. Therefore, according to the form of the conceptual curve, the final equation of motion can be obtained with the following two hypotheses.

$$\frac{de_e}{dE_l} = \frac{e_{\mu k}}{e_{\mu kmax}} \tag{Assumption 1}$$

$$\frac{de_{\mu k}}{dE_l} = \frac{K_{sh}}{K_{sh} + E_l} \tag{Assumption 2:}$$

Reminder: because of the angle between the line L and the horizontal axis (A) is 45°, it is proved that for each value of:  $\frac{dx}{dL} = \frac{dx}{dA}$ .

$K_{sh}$  is the constant of the equation. By placing assumptions 1 and 2 in Eq. 7, Eq. 8 is obtained.

$$1 = \frac{e_{\mu k}}{e_{\mu kmax}} + \frac{K_{sh}}{K_{sh} + E_l} \tag{9}$$

Therefore, the model can be solved according to the required parameters. Suppose the purpose of calculation is  $e_{\mu k}$ , in this case the equation is written as Eq. 9.

$$e_{\mu k} = e_{\mu kmax} \frac{E_l}{K_{sh} + E_l} \tag{10}$$

But you can use  $e_l = e_{\mu} - e_{\mu sT}$  instead of  $e_{\mu k}$ . In this case, the total amount of friction energy is obtained from the following equation.

$$e_l = e_{\mu kmax} \frac{E_l}{K_{sh} + E_l} \tag{11}$$

Or it is written as Eq. 13.

$$e_{\mu} = e_{\mu sT} + e_{\mu kmax} \frac{E_l}{K_{sh} + E_l} \tag{12}$$

$$E_l = E_{in} - e_{\mu sT}$$

Considering that  $e_e$  is the kinetic energy ( $k$ ) of the object, the equation can be written as follows using  $k$ :

$$k = E_l - e_{\mu kmax} \frac{E_l}{k_{sh} + E_l} \tag{13}$$

Here, the value of  $E_l$  is the work done by the force applied to the moving object.

(2) The equation of surface absorption of materials by the adsorbent.

For mass modeling, since surface adsorption is studied in this research, we reformulate the Shamohammadi adsorption isotherm model based on the aforementioned rules. For this, according to the first and second laws, we first obtain the mass–mass model, and then, based on the third law, we obtain the adsorption kinetics model. The conceptual curve of the surface absorption system of materials on the adsorbent surface is shown in Fig. 8. According to the second law, when the input concentration ( $C$ ) tends to zero, the absorption curve (Fig. 8) will be linear with an angle of 45°. The boundary between equilibrium absorption and linear absorption is called threshold of dynamic equilibrium point. Before the beginning of the equilibrium reaction, the input concentration ( $C_T$ ) and absorbed concentration ( $q_T$ ) are equal in terms of mg/liter and form the equation of a line with an angle of 45°.  $C_T$  and  $q_T$  values can be any number, even zero.

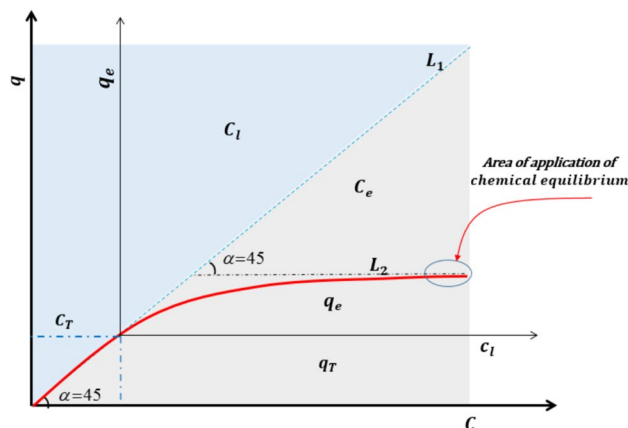


Fig. 8 Conceptual surface absorption curve

For modeling, first the  $C_T$  and  $q_T$  values are separated as constant values ( $C_T=q_T$ ) and then the equation is written based on the first law for the system variables. In this case,  $C$  is the concentration entering the system,  $C_l$  is the remaining gel ( $C_l=C_{q_T}$ ), and  $C_e$  is the equilibrium concentration of the solution and  $q_e$  is the absorbed concentration of substances on the absorbent surface (all are in mg/liter), so according to the law First:

$$1 = \frac{dC_e}{dC_l} + \frac{dq_e}{dC_l} \tag{14}$$

According to the conceptual curve of Fig. 8, the following assumptions can be written for the equation.

$$\frac{dc_e}{dc_l} = \frac{q_e}{q_{e,max}} \tag{15}$$

$$\frac{dq_e}{dc_l} = \frac{K_{sh}}{K_{sh} + c_l} \tag{16}$$

Reminder: because of the angle between the line L and the horizontal axis (A) is 45°, it is proved that for each value of:  $\frac{dx}{dL} = \frac{dx}{dA}$ .

By combining Eq. 13 with Eqs. 14 and 15, the adsorption isotherm model is obtained in terms of  $q_e$  (Eq. 16).

$$q_e = q_{e,max} \frac{c_l}{K_{sh} + c_l} \tag{17}$$

But according to Fig. 8,  $q = q_T + q_e$ , so the equation in terms of  $q$ :

$$q = q_T + q_{e,max} \frac{c_l}{K_{sh} + c_l} \tag{18}$$

Equation 18 as a mass–mass equation is comparable to Eq. 11 (energy–energy equation).

Equations 11 and 17 are examples of equations in the field of mass and energy that were examined in this section. To convert Eqs. 11 and 17 into kinetic equations (Table 1), equivalence law (third law) has been used.

Obviously, if in Figs. 7 and 8 instead of time-independent variable, the value of  $t_l$  like  $C_l$  is obtained from the result of  $t_l=t-t_T$  and  $t_k$  is used instead of the constant number  $K_{sh}$  (Eq. 15) in modeling, the kinetic equation in The crime area is obtained as in Table 1 (Shamohammadi and Shamohammadi 2024). Considering that both models of mass, mass and energy are similar, the kinetic equation in the field of energy is completely similar to the mass equation (absorption kinetics).

The equations of Table 1 are similar to the equations of motion (Eq. 18) in geometric space in classical mechanics.

$$X = x_0 + vt \tag{19}$$

As can be seen, the distance traveled ( $X$ ) in meters is equal to the initial distance (corresponding to the initial absorption or  $q_T$ ) and the second term of the distance traveled varies with the speed ( $v$ ). It can be seen that both our equations are of mass and energy and Eq. 19 is based on energy. With the difference that since the issue is mass flow (not just distance), we use the law of conservation of mass (energy). Therefore, what is important is that the equations of matter, because they are based on the flow of mass and energy, are compatible both with the concepts of space–time (geometric domain) and with the equations of motion in classical physics. This issue can add to the validity of the new equations.

## Materials and methods

### Adsorbent preparation

To prepare the absorbent, (1) walnut shells were collected by visiting the peeling workshop. (2) The absorbents were then washed. and (3) dried and (4) crushed. Then, about 50% of the material was set aside as green walnut hull (GWH) absorbent and the rest was tested to prepare biochar (GWHB).

The carbonization process was carried out by loading 250 g of dried precursor into a tubular furnace and heating to a carbonization temperature of 450 °C for 2 h under purified

**Table 1** General form of energy–energy and mass–mass models along with general energytime and masstime kinetic models

Equilibrium model	Mass form of energy	Kinetic form *	Simplified kinetic form ( $v_l = 1$ )
Body movement and energy absorption by friction	$e_\mu = e_{\mu ST} + e_{\mu kmax} \frac{E_l}{K_{sh} + E_l}$	$e_\mu = e_{\mu ST} + e_{\mu kmax} \frac{v_l t_l}{t_k + v_l t_l}$	$e_\mu = e_{\mu ST} + e_{\mu kmax} \frac{t_l}{t_k + t_l}$
Mass flow and material absorption on the absorbent surface	$q = q_T + q_{e,max} \frac{c_l}{K_{sh} + c_l}$	$q = q_T + q_{e,max} \frac{v_l t_l}{t_k + v_l t_l}$	$q = q_T + q_{e,max} \frac{t_l}{t_k + t_l}$

\* In kinetic equations such as energy equations and mass equations,  $v_l t_l$  is used instead of independent variable ( $E_l$  and  $C_l$ ) and  $t_k$  is used instead of  $K_{sh}$ . The dimensions of both sides of the equation are also respected (usually in the experiments, the input speed is considered constant in such a way that the value of  $v_l$  is equal to 1 numerically). The value of  $t_k$  in the kinetic model is a time constant whose dimension is obtained by other parameters

**Table 2** Surface area and pore characteristics and proximate analysis of the prepared samples (shamohammadi et al. 2024)

Surface area and pore characteristics of the samples					Proximate analysis (%)			
Sample	BET surface area(m <sup>2</sup> /g)	Mesopore surface area(m <sup>2</sup> /g)	Total pore volume (cm <sup>3</sup> /g)	Average pore diameter (nm)	Moisture	Volatile	Fixed carbon	Ash
GWH	137.45	79.83	0.132	2.73	3.55	20.2	73.06	3.651
GWHB	843.12	507.35	0.401	2.7	2.27	14.17	79.9	3.79

N<sub>2</sub> flow (Shamohammadi et al. 2024; Lehmann et al. 2006; Foo and Hameed 2012; Ahmad et al. 2014). The char produced was mixed with KOH pellets at different impregnation ratio (IR), defined as: IR = W\_KOH/W\_char where wKOH and wchar are the dry weight of KOH pellets (g) and char (g), respectively.

Microwaves with a frequency of 2.45 GHz were used for the activation stage. The flow rate was adjusted (300 cm<sup>3</sup>/min) to vent air from the reactor before the start of microwave heating and continued to flow during the activation phase. Different power levels and hours are set for different times of exposure to microwave power levels. The resulting activated carbon (GWHB) was successively washed with 0.1 nitric acid and water, until the pH of the solution reached 6–7 (Azizian and Yahyai 2006; Shamohammadi et al. 2024).

The yield is defined as the dry weight of activated carbon per weight of char used for activation.

Properties of adsorbents.

To determine the properties of green walnut hull (GWH) and green walnut hull biochar (GWHB) adsorbents, Fourier transform infrared spectroscopy (FTIR) and BET method and surface morphology with electron microscope (SEM) were used and the results are in Table 2.

### Adsorption model

Adsorption models include isotherm and adsorption kinetic models for years, which have been used as a tool in the estimation of absorption properties, such as adsorbent capacity, adsorption equilibrium time, and the form of substance absorption behavior by the adsorbent.

### Kinetic models

One of the important goals of absorption kinetics models is to show the time process of absorption, which makes it possible to calculate the speed of absorption and the time required to reach the equilibrium of the absorption system (Shamohammadi et al. 2013; Shamohammadi et al. 2024).

In this research, four first-order and pseudo-first-order kinetic models (PFO), second-order and pseudo-second-order kinetic model (PSO), Shamohammadi model (Shamohammadi et al. 2024) and the new model were selected to evaluate the “absorption time” process. The advantage that

these models have over other kinetic models is that all four models are able to calculate the absorbent capacity. With the difference that the PFO and PSO models are empirical, but the Shamohammadi kinetic model and the modified Shamohammadi model have a theoretical basis.

**PFO model** The PFO model fits the data well at low concentrations, but shows the absorbent capacity less than reality (Ahmad et al. 2014). The first-order and pseudo-first-order kinetic models are shown in Table 3.

**PSO model** The pseudo-second-order kinetic model is based on the assumption that the rate-limiting step of adsorption is chemical adsorption. In this situation, the adsorption rate depends on the properties of the adsorbent and not on the concentration of adsorbed substances (Ahmad et al. 2014; Bhanvase et al. 2021). PSO and PFO models are theoretically only able to calculate the equilibrium adsorption capacity.

**Shamohammadi kinetic model** Shamohammadi presented his isotherm model based on the conceptual adsorption curve and dynamic mass conservation law. Then, by introducing the mass–time equivalence law (Shamohammadi and Shamohammadi 2024), he used the parameter *t* instead of the independent variable in the adsorption isotherm model (C). Shamohammadi’s kinetic model, in addition to calculating the adsorption capacity, is very simple (Table 3). The definition of adsorption parameters is also shown in Table S5. In this study, we will use the previous Shamohammadi model and the new model (Table 3) to study absorption kinetics.

**Table 3** Adsorption kinetic PFO, PSO and Shamohammadi models

Model	Mathematical model	References
PFO	$q_t = q_e \left[ 1 - \frac{1}{e^{k_1 t}} \right]$	Lagergren(1898)
PSO	$q_t = \frac{k_2(q_e)^2 t}{1 + q_e k_2 t}$	Ho et al. (1999)
Shamohammadi	$q_t = q_{max} \frac{t}{t_k + t}$	Shamohammadi and Shamohammadi (2024)
Shamohammadi	$q_t = q_T + q_{e,max} \frac{t}{t_k + t}$	مطالعه حاضر

## Isotherm models

In this study, three adsorption isotherm models of Langmuir, Shamohammadi and the new model (modified Shamohammadi) are used (Table 4). The reason for choosing the models is that the Langmuir model, Shamohammadi model and the new model have a theoretical basis and estimate the adsorbent capacity (Alafnan et al. 2021).

**Langmuir adsorption isotherm model** Langmuir (1918) first presented his equation for the adsorption of gases (Shamohammadi et al. 2024). Then, in 1918, he introduced the equation of adsorption in aqueous solutions as it is today (Table 4).

Shamohammadi adsorption isotherm model.

Shamohammadi in 2016 (Shamohammadi et al. 2022) presented his model using the dynamic mass conservation law (first law), but to avoid complex operations, in 2022 (Shamohammadi et al. 2022) from its simplified form used. Although he reviewed his original equation in 2024, he used his simplified equation (Shamohammadi et al. 2022) to calculate the adsorbent capacity. In this study, we will use both the new model (modified Shamohammadi) and the Shamohammadi model (Table 4).

## Bach test

In this study, Titraxel ions of Fe<sup>2+</sup>, Pb<sup>2+</sup>, Zn<sup>2+</sup>, Ni<sup>2+</sup>, Cd<sup>2+</sup> and Cu<sup>2+</sup> (purchased by Merck, Germany) with a purity between 95 and 99% were used to prepare the standard solution (Yu W 2020). Deionized water was used to make the stock solution (1000 ppm) according to the standard methods of water and wastewater laboratories (Standard Methods for Water and Wastewater Examination).

## Adsorption kinetics experiments

**Determining the adsorption equilibrium time** To determine the adsorption equilibrium time, we used a new method to compare the adsorption values in the chemical adsorption range (adsorption of elements in concentrations lower than CT) with adsorption in isotherm conditions, in such a way

that the number of 10 Erlenmeyer selected and the solution Fe<sup>2+</sup> + metal with initial concentrations of 10 mg/L to 200 mg/L was poured into each of them. Also, 1 g of adsorbent (10 mg/L) GWHB was poured into each of the flasks and placed on the shaker. Then, for each concentration of metals, ten Arlen Meyers were selected and placed on the shaker for different times. After the passage of different times (from 10 min to 10 h), the solution was removed from the shaker. Then, the remaining solution was passed through a Whatman sieve and the concentration of Fe<sup>2+</sup> + remaining in the solution was measured. This work was repeated for the rest of the metals and adsorbents (at laboratory temperature). Based on studies (Pehlivan et al. 2012; Lu et al. 2009), the pH value was chosen equal to 6 in all experiments. Also, from the data extracted from this part, adsorption kinetic models were also studied (Nadaroglu and Kalkan 2012).

**Adsorption isotherm experiments** Adsorption isotherm experiments were also performed similar to kinetic experiments. The only difference between them is that instead of the change in time, the change in the initial concentration (C) was used (Shamohammadi et al. 2024). In this part of the experiment, the initial concentration of Erlenmeyer was chosen between 10 and 200 mg/L (Yu W et al. 2020). Then Erlenmeyer flasks were placed on the shaker for 6 h for each of the metals and each of the adsorbents (based on the results of the kinetic tests).

## Model evaluation

About half of the test data were selected for calibration and the other half for evaluation. The stages of calculating the adsorbent capacity (chemical, physical and total) and evaluating the model were done. For evaluation, three evaluation criteria including determination coefficient (R<sup>2</sup>) and root mean square error (RMSE) were used (Eqs. 20, 21).

$$R^2 = \left( \frac{\sum_{i=1}^N (Q_{\text{obs}} - \overline{Q_{\text{obs}}})(Q_{\text{sim}} - \overline{Q_{\text{sim}}})}{\sqrt{\sum_{i=1}^N (Q_{\text{obs}} - \overline{Q_{\text{obs}}})^2 (Q_{\text{sim}} - \overline{Q_{\text{sim}}})^2}} \right)^2 \quad (20)$$

**Table 4** Mathematical models of Langmuir, Shamohammadi and new adsorption isotherms

Theoretical basis	Independent variable	Mathematical equation	Model
The principle of chemical equilibrium	to equilibrium concentration (C <sub>e</sub> )	$q_e = q_{\text{max}} \frac{K_1 C_e}{1 + K_1 C_e}$	Nimibofa et al. 2017
Law of conservation of mass (dynamic mass equation)	Initial concentration of solution (C)	$q = q_{\text{max}} \frac{C}{K_{sh} + C}$	Shamohammadi (Shamohammadi et al. 2022)
Law of conservation of dynamic mass (dynamic mass equation)	Initial concentration of solution (C)	$q = q_T + q_{e, \text{max}} \frac{c_T}{K_{sh} + c_T}$	مطالعه حاضر



$$\text{RMSE} = \sqrt{\frac{1}{N} \left( \sum_{i=1}^N (Q_{\text{obs}} - Q_{\text{sim}})_i \right)^2} \quad (21)$$

where  $Q_{\text{obs}}$  is the amount of observed runoff,  $Q_{\text{sim}}$  is the amount of simulated runoff (model), and  $N$  is the number of data.

## Discussion

### Absorbent properties

#### BET surface area and pore characteristics

Table 2 shows the BET surface area and pore characteristics of GWHB and GWH samples. The BET surface area and total pore volume for GWHB were 941.02 m<sup>2</sup>/g and 0.47 cm<sup>3</sup>/g, respectively; these values are comparable with the commercial GWHB and PP char (Ahmad et al. 2014) which were reported to have BET surface area of 941.02–115.30 m<sup>2</sup>/g and total pore volume of 0.470 and 0.120 cm<sup>3</sup>/g, respectively. The average pore diameter for GWHB was 2.70 nm. It belongs to the mesopore region according to IUPAC classification (Everett 2009). The microwave-assisted KOH activation step had contributed to the high surface area and total pore volume of the GWHB which were advantageous for dye adsorption. The intercalation of the KOH with carbon was important in the generation of well-developed pores, thus creating large surface area and high pore volume (Hui and Zaini 2015).

Surface morphology.

The surface morphology of GWHB is shown in Fig. 9 for two states before carbonization (A) and after carbonization (B) with a magnification of 6000. As can be seen, before carbonization, there are pores on the surface, but they are not deep and wide, but after the physicochemical activation

stage (Fig. 9b), it can be seen that the pores on the surface are deeper and more developed, so that the surface has become more uneven.

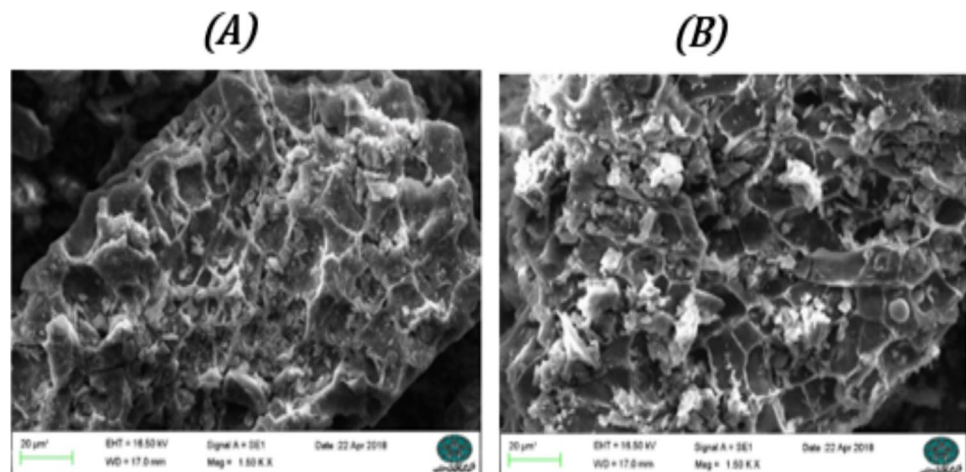
It seems that the development of pores is caused by the decomposition of some materials due to thermal expansion during the period (Ahmad et al. 2014).

There action rate between the activating agent which is KOH and carbon also increases when the precursor is subjected to high activation temperature, thus leading to the formation of well-developed pores (Sun and Webley 2010). The porosity and surface area of the GWHB increased as there action between carbon and KOH led to the formation of new pores due to loss of volatile compound during the physicochemical activation step (Auta and Hameed 2011).

#### FTIR studies

The results of FTIR test to determine functional groups of biochar surface are shown in Fig. 10. The 515 cm<sup>-1</sup> band shows the stretching vibration of C–Br groups of alkyl halides. Peaks at 738 and 873 cm<sup>-1</sup> caused the C–H stretching vibration of the aromatic group, while the 1022 cm<sup>-1</sup> band is related to the carboxylic acids and esters in cellulose and hemicellulose (C–O–C stretching). Peak at 1323 cm<sup>-1</sup> related to the peak of phenolic groups and lignins O–H bending, C–O stretching, peak at 1428 cm<sup>-1</sup> related to cellulose carboxyl CH<sub>2</sub> group, peak at 1615 cm<sup>-1</sup> related to aromatic compounds, ketones and quinones (C=C and C=O), the 1795 cm<sup>-1</sup> peak corresponds to the C=O stretching vibration of ketone and ester groups, the 2920 cm<sup>-1</sup> peak corresponds to the C–H stretching vibration of the CH<sub>x</sub> alkanes group. Also, the 3415 cm<sup>-1</sup> peak is related to the O–H stretching vibration of alcoholic and phenolic groups (Shamohammadi et al. 2024).

**Fig. 9** GWHB surface morphology with 6000 magnification power for two states A) before carbonization and B) after carbonization (Shamohammadi et al. 2024)



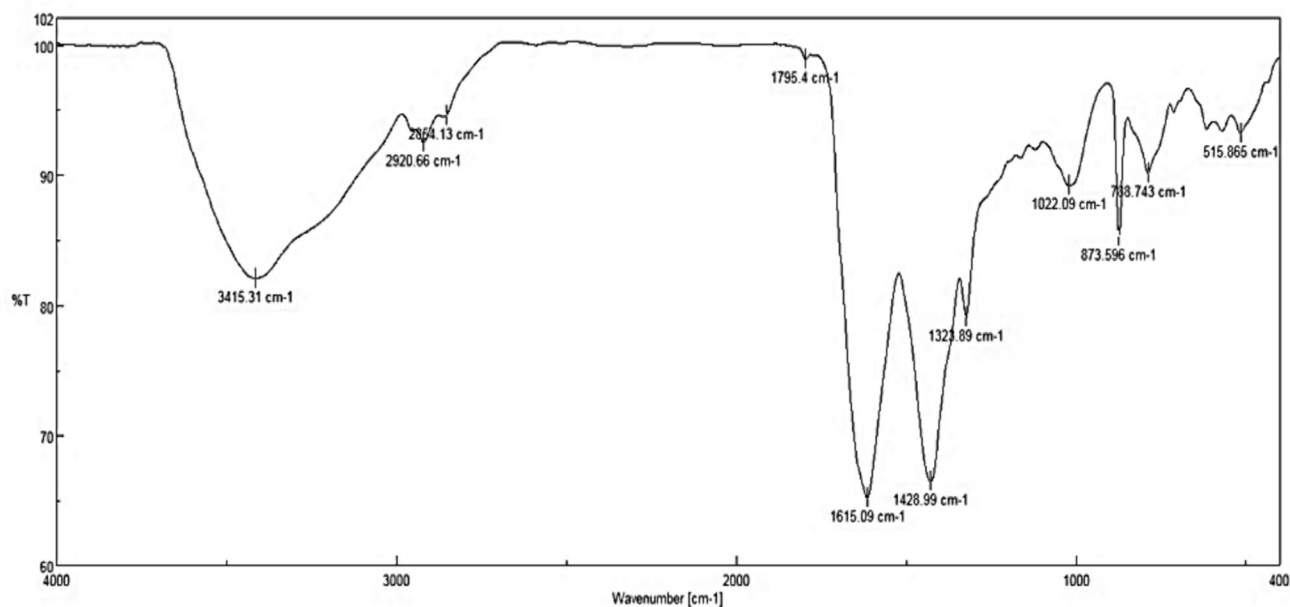


Fig. 10 FTIR spectrum of biochar adsorbent (Shamohammadi et al. 2024)

### Batch adsorption studies

In Fig. 11, the absorption values of heavy metals by GWHB are shown with time. As can be seen, the absorption rate with respect to time ( $\Delta q/\Delta t$ ) is initially high for all elements, so that for a time of one hour, up to a concentration of 10 ml Gram/liter, all elements were absorbed 100% by GWHB adsorbent, then except Cd and Cu, the rest of the elements were completely absorbed up to 20 mg/liter, and Fe and Pb elements were absorbed 100% up to 40 g/liter. In fact, before the equilibrium, where the concentration of the elements is very low, all the adsorbents can absorb all the elements and have an irreversible reaction (first law); as a result, the

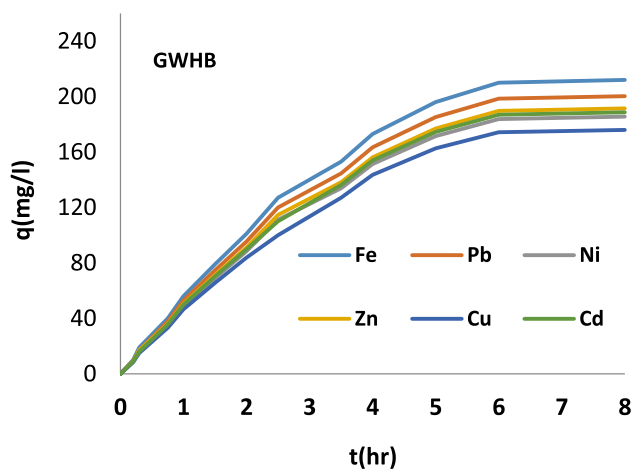


Fig. 11 Surface adsorption of heavy metals with time (GWHB adsorbent, pH=6, T=21 ± 2 °C)

absorption is linear with an angle of 45° for all the adsorbents (the maximum is equal to 1 mg/L/min). These results are consistent with the results of studies by Shamohammadi et al. (2024).

After the complete absorption of the elements, in the next concentrations, the rate of absorption decreases and the bending of the mass of time becomes visible. As seen in Fig. 11, as time increases, in addition to the reaction speed decreasing for all metals, the distance between the curves also increases. In fact, the difference in absorption power becomes more real at higher concentrations, because absorption becomes a function of the absorption force between the metal and the adsorbent, and the concentration plays a smaller role. In 6 h, almost the slope of changes for all elements becomes zero (Shang 2013; Al-Ghouti and Da'ana 2020). The absorption of elements in 6 h varies between 17.51 mg/g for Cu and 21.02 mg/g for Fe. From 6 to 10 O'clock, the absorption changes for all elements are constant and the increase in the amount of absorption is very small (Ahmad et al. 2014; Brandani 2020).

### Kinetic models

Figure 12 shows the fit of the kinetic models on the test data of heavy metal absorption by GWHB. Also, Table 5 shows the adsorbent capacity of the kinetic models along with their evaluation. As can be seen, the curves of the kinetic models are very close to each other, as if they coincide, while the calculated adsorbent capacity values by them are together. Is different. Based on the evaluations of the models

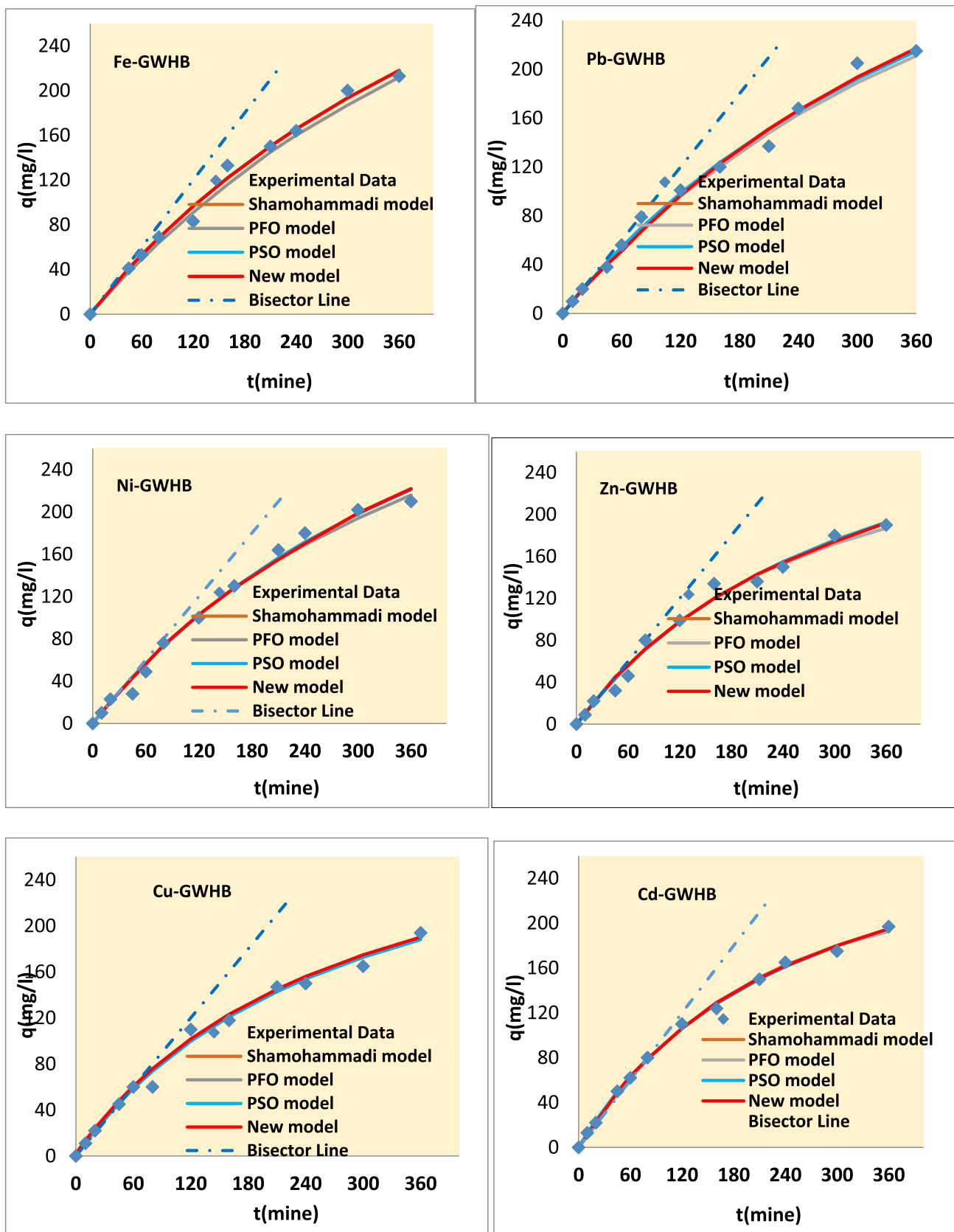


Fig. 12 Fitting of Shamohammadi, PFO, PSO and new models to absorption test data (GWHB adsorbent, pH=6, T = 21 ± 2 °C)

**Table 5** Absorption capacity of heavy metals by GWHB adsorbent estimated by absorption kinetic models

Heavy metals	Shamohammadi model	New model		PSO model	PFO model	RMSE	R2
	qmax (mg/g)	q <sub>emax</sub> (mg/g)	q <sub>T</sub> (mg/g)	q <sub>e</sub> (mg/g)	q <sub>e</sub> (mg/g)		
Fe	58.565	54.702	4	58.565	32.561	between.621 to5.332	between.983 to.994
Pb	55.482	50.653	4.00	53.216	32.523		
Zn	37.518	39.032	2	37.543	24.138		
Ni	42.977	40.757	2	42.94	31.662		
Cd	35.035	35.39	1.00	35.41	22.593		
Cu	34.331	33.333	1.00	33.789	22.488		
Average	43.984	42.33	2.33	43.577	27.66		

(Table 5S), for all three models, the average value of R2 varies between 0.983 (PFO model) and 0.994 (new model). Also, the average value of RMSE varies between 4.621 for the new model and 5.332 for the PFO model. These indices show that all three models explain the experimental data well, but the general form of the models shows that in the absorption process of all metals (by GWHB), the Shamohammadi model and the new model agree with the PSO model. All four models are consistent in the initial times, but the PFO model shows lower absorption values as time increases. The reason for the decreasing slope of the curves of the PFO model compared to other models is that the term ( $\frac{1}{e^{k_1 t}}$ ) is a decreasing exponential parameter that causes a faster decrease in the slope of the curves of the PFO model as time increases (Munmun et al. 2018; Lu et al. 2009). For this reason, the absorbent capacity of the PFO model is much lower than that of other models. The difference between the absorption capacity of PSO and PFO models in the studies (Guo and Wang 2019) is completely consistent with the results of the present studies. In mathematical models, the absorbing capacity is reached when time goes to infinity. On the other hand, the compatibility of the two Shamohammadi models and the new model with the PSO model is because the mathematical form of both models is completely the same, because if we divide the numerator and denominator of the PSO model by “ $[[q_e k_2]$ ”, the general form of the model is  $q_t = q_e / t \left[ \left( \frac{1}{q_e k_2} \right) + t \right]$  will be (see Table 3). Comparing it with the new model [ $q_e = q_{emax} (t / (t_k + t))$ ] shows that  $t_k = \frac{1}{q_e k_2}$ . In other words, the models are completely similar in terms of format. This comparison is given in Table 5.

The difference between the new model and the Shamohammadi model is in the separation between equilibrium capacity (physical) and chemical capacity ( $q_T$ ). Also, the form of the equilibrium part of the new model is completely the same as the Shamohammadi model and the PSO model.

Also, comparing the capacity of absorbers in two Shamohammadi and PSO models confirms that these two models are identical (Shamohammadi and Shamohammadi 2024),

but the capacity of the absorber in the new model is different from the others. The reason is related to the separation of primary absorption (chemical absorption) and physical absorption of adsorbents, which is calculated by the new model, in total, the overall capacity of the adsorbent is the same in all three methods, with the difference that the new model is chemical capacity and physical capacity. It is calculated separately and more accurately (based on evaluation indicators).

The average adsorption capacity of GWHB was estimated by Shamohammadi model and PSO model to be 43.984mg/g and 43.577mg/g, respectively, which means there is almost no difference. The average adsorption capacity of GWHB by PFO model is 27.66 g/mg. That is, the difference in the calculation of absorbent capacity in the PFO model is more than 38.2% on average. In other words, the estimation of absorbent capacity by PFO model is on average 37.2% lower than Shamohammadi model and PSO model. Meanwhile, the average equilibrium capacity calculated by the new model is 42.33 mg/g, including the amount of chemical absorption (2.33), the average value of the total adsorbent capacity of GWHB is 44.66 mg/g, which is a significant difference with the two mentioned models. does not have. Therefore, the new model is not significantly different from the Shamohammadi model in terms of calculating the absorbent capacity, it is only more accurate in separating the capacities.

In the studies of Bhanvase et al. (2021), it is said that  $q_e$  is the equilibrium capacity in PFO and PSO models. This is not true, because in practice, the curves of PFO and PSO models are drawn based on data that starts from zero (like our model). On the other hand, based on these models (Table 3), when time tends to infinity, the value of  $q_e$  is obtained. Therefore, both theoretically and in terms of the obtained capacity values (Table 5), the aforementioned models calculate the total capacity of the absorber. The only difference between them is that they do not have a theoretical basis and are experimental, for this reason they are not able to separate chemical capacity and physical capacity. In addition, such models cannot participate in the equivalence law process, because they are not based on the first law.

In general, the compatibility of the new model with other models, very good evaluation indices, and the comparison of the new model form with the PSO and Shamohammadi models show that the basics of the new modeling have worked well.

### Investigating the bending masstime

In Fig. 12, the bisector line shows the maximum rate of transfer (or conversion) of heavy metals on the absorbent surface. In other words, the transfer rate or absorption rate on the bisector line is equal to  $v = (\Delta q(\text{mg/L})) / (\Delta t(\text{min})) = 1((\text{mg/L})/\text{min})$ . Therefore, based on Fig. 12, all heavy metals are first (before equilibrium) absorbed by the absorbent surface with the maximum possible speed, and there is no mass–time bending (one-way reaction), but when the equilibrium reaction begins, the rate (speed) of the reaction is reduced, as a result of time–mass bending is observed ( $v \leq 1((\text{mg/L})/\text{min})$ ). As mentioned earlier, the meaning of time bending is special time bending which always changes with the change of phenomenon. For example, the curves in Fig. 12 are the output masses of the system, which decrease with the uniform increase of time (time on the horizontal axis). The time shown on the horizontal axis is the local (observer) time adjusted to the input mass, thus for the input mass it forms a line with an angle of  $45^\circ$ , but for the output mass and the specific time of the output mass, It is not necessarily a line with an angle of  $45^\circ$ . For this reason, at the beginning, when the reaction is one-way (the first law), the output mass and, accordingly, the specific time of the output mass form a line with an angle of  $45^\circ$  with the time axis, but then, when the system reaches equilibrium, the speed of the reaction decreases. As a result, the output mass of the system, along with its specific time, are bent relative to the horizon axis. Finally, when the absorption system is in perfect equilibrium, with increasing time (on the horizontal axis), the output mass does not increase (displacement of the molecules of the system is displaced and there is dynamics in microscopic conditions, but the net mass transfer is zero), as a result, the specific time of the output mass will also be zero (the time of the output mass brings cache).

Therefore, the curvature of mass–time here is comparable to the curvature of space–time in general relativity. In space–time, when a particle of light moves toward the center of gravity, its speed ( $C$ ) slows down as it approaches the center of gravity (Yuan 2024). In fact, the rate of change in particle energy decreases, on the other hand, since each particle (phenomenon) has a special time (the fourth dimension of space–time) with it, with the decrease of changes in particle energy, the special time also expands and slows down. It was already mentioned that the special time of each phenomenon depends on the change of that phenomenon).

In this case, the particle and its specific time (due to the decrease in speed or decrease in energy change) are bent.

In classical physics and in the field of mass and energy flow, the maximum speed of transformation or transfer is equal to 1 (according to the law of sustainability: the maximum output mass of the system can be equal to the maximum input mass of the system) which corresponds to the maximum speed in relativity physics, i.e., the speed of light in vacuum. It is about 300,000 km per second.

### Adsorption isotherm models

Table 6 shows the output of Shamohammadi, Langmuir and new isotherm models. As can be seen, all models explain the absorption data well, so that  $R^2$  is between 0.963 (for Zn absorption by GWH adsorbent) and 0.999 (for Fe, Pb, Zn and Ni metal absorption by GWHB adsorbent) for the Shamohammadi model and the new model is different. Although  $R^2$  is less related to the Langmuir model, this result is acceptable in terms of evaluation indicators. This is also confirmed by the RMSE index. The highest RMSE is related to the absorption of nickel by the Langmuir model, which is equal to 14.179 and indicates the average fit of the model, but in general, the average RMSE for the Shamohammadi model, Langmuir and the new model is 0.748, 8.263 and 0.747 for the GWHB absorber, respectively. GWH is 1.425, 8.412 and 1.422, which shows that the models were able to fit the data well, while the Langmuir model is less accurate.

The average capacity of GWH and GWHB adsorbents by Shamohammadi model is 27.323 mg/g and 46.935 mg/g, respectively, while the average capacity of adsorbents by Langmuir model is 14.683 mg/g and 16.967 mg/g, respectively. Meanwhile, the new model has estimated the equilibrium (physical) capacity of GWH and GWHB adsorbents as 26.656 mg/g and 44.661 mg/g, respectively. As can be seen, the difference in calculating the adsorbent capacity for two new models (physical capacity) and Shamohammadi (maximum capacity) is less than 5%, but the difference between the calculated capacity values of Shamohammadi model and Langmuir model is between 1.9 and 3 t. Regarding the comparison between the Shamohammadi model and the new model, including the chemical capacity, for GWH and GWHB adsorbents, the calculation difference in the two models is + 1.003 and – 2.274 mg/g, respectively, which is completely negligible. This shows that Shamohammadi's equation (simplified new equation) can also be used to calculate the total capacity of the absorber. Therefore, the calculation of the maximum capacity in the studies of Shamohammadi et al. (2024) has been done correctly, but the calculation of the chemical and physical capacity by them is theoretically and practically incorrect.

**Table 6** Output of Shamohammadi, Langmuir and new model isotherms ( $T = 21 \pm 2^\circ\text{C}$  and  $\text{pH} = 6 \pm 0.2$ )

Absorbent	Heavy metals	Shamohammadi model				Langmuir model				New model					
		qmax (mg/g)	$K_{sh}$	RMSE	R2	qmax (mg/g)	RMSE	R2	qchem (mg/g)*	qmax (mg/g)	RMSE	R2			
GWHB	Fe	58.565	57.058	1.177	0.999	19.906	6.965	0.976	4	54.702	1.175	0.999	58.702	1.175	0.999
	Pb	55.469	56.927	1.643	0.999	16.886	7.008	0.975	4.00	50.653	1.640	0.999	54.653	1.640	0.999
	Zn	43.698	42.365	0.638	0.999	15.792	8.539	0.974	2	39.032	0.638	0.999	41.032	0.638	0.999
	Ni	42.937	41.532	0.428	0.999	15.203	9.286	0.971	2	40.757	0.428	0.999	42.757	0.428	0.999
	Cd	34.932	29.544	1.963	0.998	13.551	10.087	0.979	1.00	35.39	1.953	0.998	36.39	1.953	0.998
Average GWH	Cu	34.007	28.866	3.842	0.992	15.817	6.936	0.981	1.00	33.333	3.842	0.992	34.333	3.842	0.992
	Fe	46.935	46.985	0.748	0.999	16.967	8.263	0.974	2.33	42.331	0.747	0.999	44.64	0.747	0.999
	Pb	32.148	32.042	3.821	0.996	15.822	6.244	0.996	2	31.15	3.754	0.996	33.15	3.754	0.996
	Zn	33.045	26.547	3.879	0.993	13.809	5.237	0.984	2	33.12	3.879	0.993	35.12	3.879	0.993
	Ni	23.335	19.065	2.056	0.997	11.911	5.261	0.963	1	23.51	2.056	0.997	24.51	2.056	0.997
Average	Cd	23.932	24.545	3.25	0.993	12.551	14.179	0.888	1	23.051	3.25	0.993	24.051	3.25	0.993
	Cu	29.845	28.965	0.462	0.999	13.995	5.919	0.983	2	28.21	0.462	0.999	30.21	0.462	0.999
	Fe	22.265	17.67	2.448	0.996	10.960	10.062	0.922	2	20.897	2.448	0.996	22.897	2.448	0.996
	Pb	27.323	35.589	1.425	0.997	14.683	8.412	0.961	1.67	26.656	1.422	0.997	28.326	1.422	0.997
	Zn														

\*qchem ( $q_T$ ) is calculated using the experiment (where the equilibrium concentration of  $C_e$  is equal to zero)

Also, the range of adsorbent capacity in Shamohammadi model is between 22.26 mg/g of copper absorption by GWH to 58.56 mg/g of iron absorption by GWHB, that is, 36.3 mg/g, while the range of calculation of adsorbent capacity in Langmuir model is between 10.960 for absorption of Cu by GWH adsorbent and 19.9 mg/g Fe absorption by GWHB adsorbent. In terms of the range of changes, the new model and the Shamohammadi model are more flexible (Shamohammadi et al. 2024). The point that should be mentioned is that according to the chemical capacity values (Tables 6 and 7), concentrations lower than  $q_T$  do not have a great impact on the adsorbent capacity (calculated by the model). Therefore, the huge difference between the estimation of the new and Shamohammadi models with the Langmuir model is due to the basic modeling assumptions and theories (Shamohammadi et al. 2024). Shamohammadi et al. (2024) showed that using the balance principle (derived from the law of conservation of mass in the form of  $\partial M/\partial t = 0$ ) is not able to model. Therefore, previous studies (Shamohammadi et al. 2022, 2024) show that the Langmuir model has fundamental flaws and cannot estimate the real capacity.

The difference in the absorption capacity of GWH and GWHB is also important, because on average, the absorption capacity of heavy metals (Table 6) by GWHB is about 1.7 t that of GWH absorption. This shows that carbonization with N<sub>2</sub> gas and combination with KOH has a great effect on increasing the capacity of GWH. These results are consistent with the results of Shamohammadi et al. (2024).

As expected, the absorption capacity calculated by the kinetic and isotherm equations (new model and Shamohammadi model) completely match (Tables 5 and 6), because based on the equivalence law as in the first law (dynamic mass equation) (instead of mass) If energy (time) is used, the equations of kinetic (mass–time) and isotherm (mass–mass) completely coincide.

To compare the absorption capacity of GWHB with other agricultural residues, the capacity calculated by the Langmuir model is used, because previous studies have also estimated the absorption capacity based on the Langmuir model. Therefore, it can be said that the maximum absorption of Cu<sup>2+</sup> metal by barley straw has been reported as 4.64 mg/g (Pehlivan et al. 2012), while in the present report, the GWHB adsorbent has absorbed a maximum of 15.817 mg/g of Cu<sup>2+</sup>. This issue for the absorption of Pb<sup>2+</sup> by activated red mud and orange peel biochar adsorbents, it is 6 (Nadaroglu et al. 2012) and 27.86 mg/g (Sreenivas et al. 2014), respectively, while in the present study, the capacity of Pb<sup>2+</sup> absorption by GWHB is 16.886 It is mg/g and shows that its absorption capacity is about 0.7 t that of Orange peel biochar and 2.5 t that of Activated Red Mud. For Ni<sup>2+</sup> absorption by Cashew Nut, Zn<sup>2+</sup> absorption

by Activated Red Mud and Cd<sup>2+</sup> absorption by Sulfonated Biochar are 18.86 (Qureshi and Aziz 2020), 14.9 (Nadaroglu et al. 2012) and 85.76 (Yu W et al. 2020), respectively, while the same Elements are absorbed by GWHB with capacities of 15.203, 15.792 and 13.551. Therefore, except for the sulfonated biochar adsorbent, which is highly effective in absorbing Zn<sup>2+</sup> in general, it can be said that the carbonization of GWH makes it more competitive, and it can be used as a cheap adsorbent.

As can be seen, the curves of the new model and Shamohammadi completely coincide. Considering the form of the new model, it was expected that the first part of the curve, which includes chemical absorption, would not be compatible with the curve of the Shamohammadi model, but since the method of drawing the curve is the same in both models, the curves of both models coincide. In fact, the main difference between the two Shamohammadi models and the new model is in the calculation of  $q_{chem}$  chemical absorption (not the curve form and total capacity). This issue has also been considered in the studies of Shamohammadi et al. In their self-confessed studies, to simplify the model, they remove a part of it that is assumed to be insignificant. On the other hand, they directly calculated the maximum capacity ( $q_{max}$ ). Then, they calculated the physical capacity in another way, which is an error (Shamohammadi et al. 2024), while in the new model, chemical capacity ( $q_{chem} = q_T$ ) and physical capacity ( $q_{max}$ ) were used separately in the model

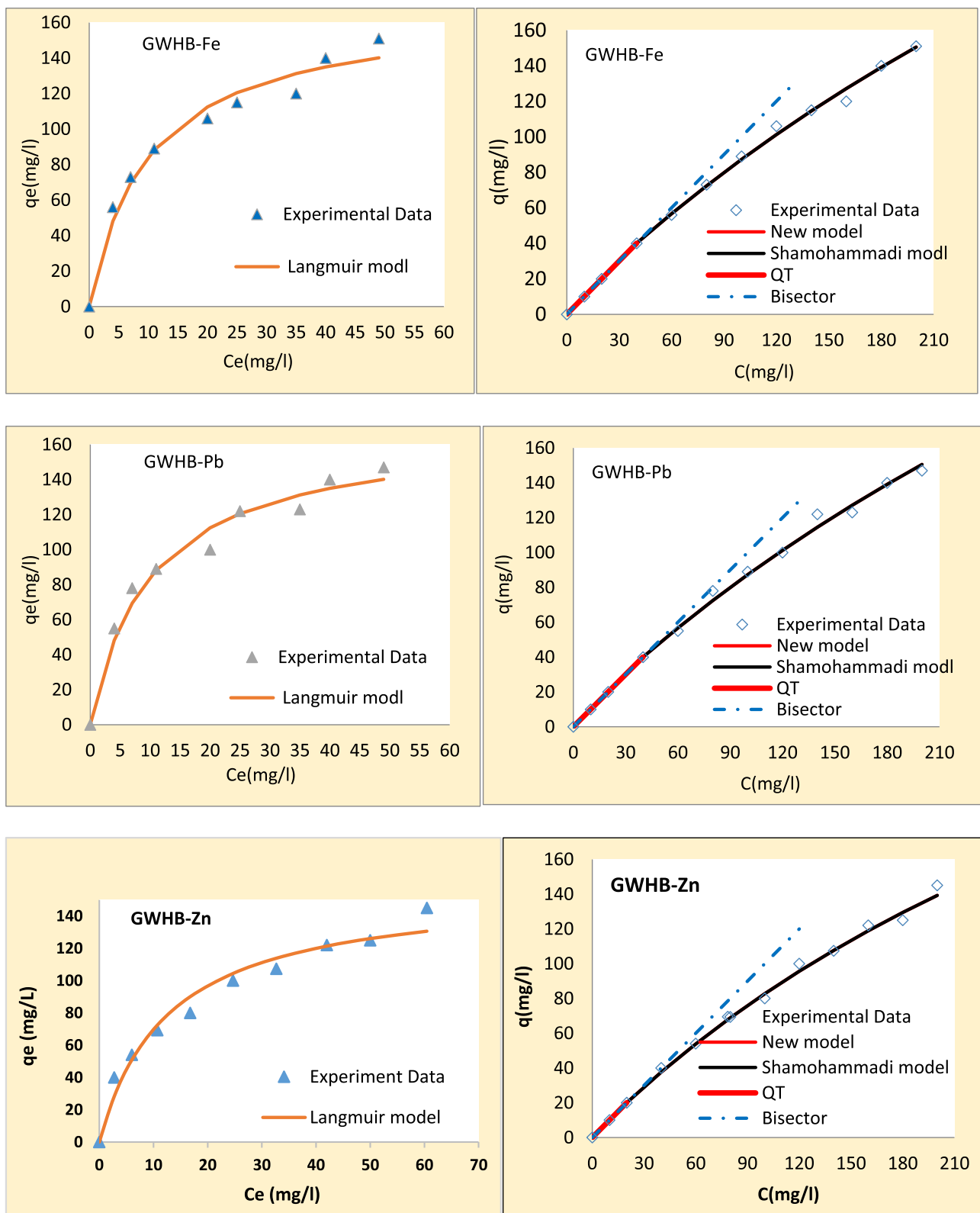
In other words, despite the fact that they presented the law of irreversibility return, they consciously ignored the constant value ( $q_T$ ) of the mass–mass equation (Table 1) in the calculations and directly included the maximum capacity in the model (Shamohammadi et al. 2024). Therefore, in practice, the calculated maximum capacity of the new model is not significantly different from the Shamohammadi model, but the new model is written in accordance with the third law and takes into account the separation of chemical and physical capacities.

Therefore, it can be said, whenever the goal is to calculate the total capacity of the absorber, the Shamohammadi equation can also be used (see Table 6). Therefore, the weakness of the Shamohammadi model is in separating the chemical capacity of the adsorbent from the total capacity.

Therefore, the new model, in addition to having a good efficiency, based on the curve format and the values of the chemical and physical capacities also shows that it is completely consistent with the similar kinetic model. This confirms the first, second and third laws.

### Bending massmass (energy–energy)

In Fig. 13, together with the curves of the Shamohammadi model and the new model, the bisector line of the coordinate



**Fig. 13** Absorption isotherm curves by the new model, Shamohammadi model and Langmuir model ( $T=21 \pm 2^\circ\text{C}$  and  $\text{pH}=6 \pm 0.2$ ). QT in the curves of the figure is the same as the chemical capacity



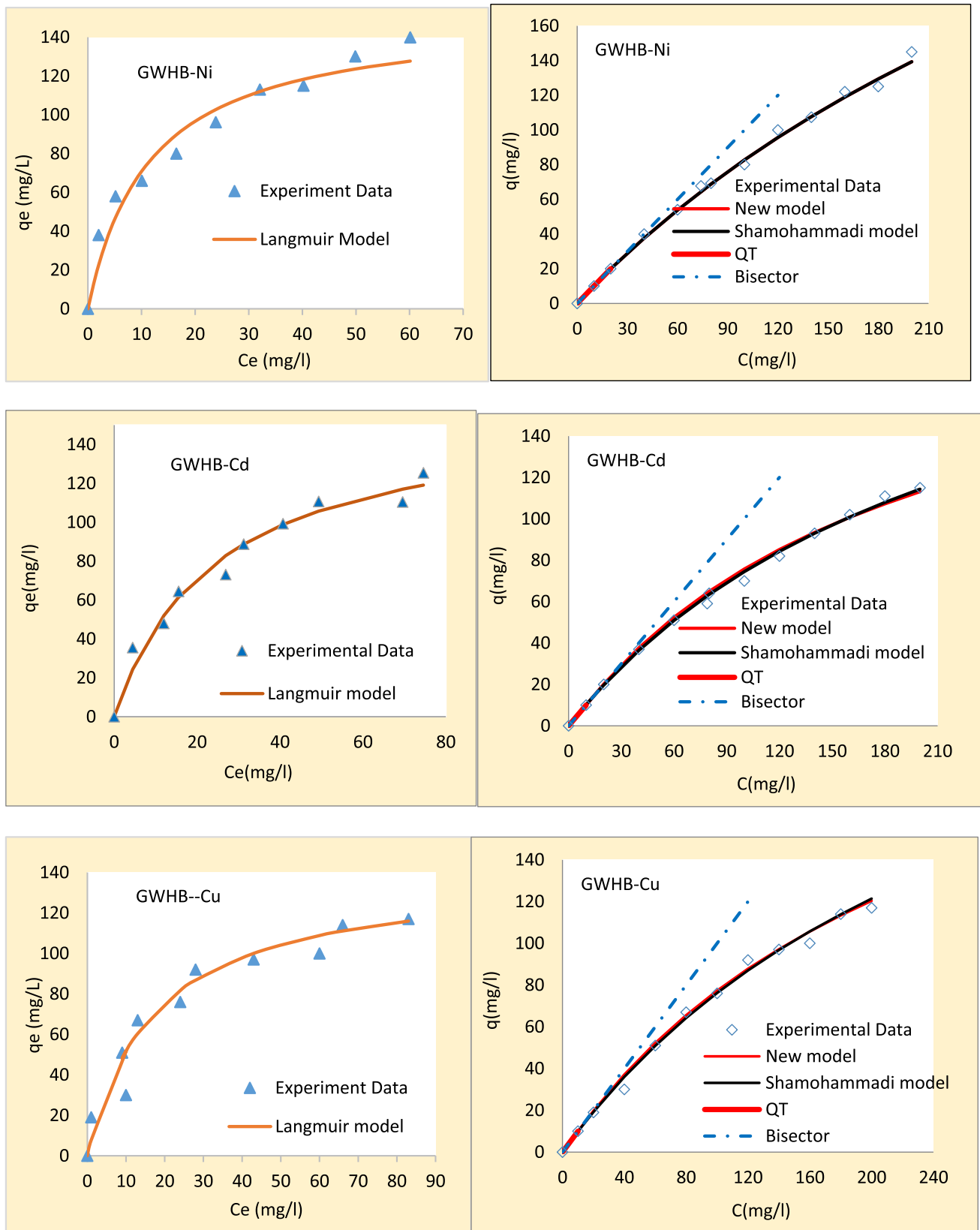


Fig. 13 (continued)

axis is also shown (this issue is not practical for the Langmuir model, because the Langmuir model is written based on the principle of balance and the law of conservation of mass is not observed in it).

As can be seen, just like the kinetic curves (Fig. 12), the adsorption isotherm curves also coincide with the bisector line before the system reaches equilibrium (chemical adsorption, QT). But with the beginning of the absorption equilibrium part, the absorption isotherm curves (mass–mass curves) are bent. In other words, the curvature of the mass of the mass is seen.

Maybe the term “curvature of mass–mass” may seem strange, but the truth is that basically one should introduce the curvature of mass–mass and the curvature of energy–energy as a principle, then the curvature of mass–time, energy–time or the curvature of space time should be concluded from it.

This claim is based on the law of equivalence (the third law), which itself is based on the Law of conservation of mass change (the first law). Reviewing the definitions of “phenomenon” and “time” mentioned earlier convinces us to accept that mass is bent with respect to mass (or energy with respect to energy) and according to that mass (energy) is bent with respect to time.

To establish a connection between the concepts of space and time with the concepts of mass and energy in classical physics, the example of Fig. 14 can help us.

Although the discussion of space time is very complicated, the above example (Fig. 14) is used to expand the curvature of space time to the curvature of mass, energy and time in classical physics. Also, light contains mass and energy, but for simplicity, we call it energy instead of light.

In Fig. 14, consider a light package moving in space ( $S$  line). In Fig. 14a, where light travels in a vacuum, at any point, the energy input ( $E_{in}$ ) is equal to the energy output ( $E_{out}$ ). Therefore, the rate of change of output energy to input energy at any point is equal to 1. When the same light package moves toward a center of gravity (for example, a black hole), the light (energy) is bent toward the black hole (Fig. 14b), in fact, the changes in light energy compared to the input energy (horizontal axis of Fig. 14b) (bent, so that when it gets close to the black hole, it loses all its energy (event horizon) and after that, with the increase of the input energy, the output energy does not increase in any way (its angle with the horizon axis) becomes zero). In this case, the angle of increase of light energy compared to light packages that are not affected by gravity is equal to  $45^\circ$ . Obviously, part of the remaining light energy is separated as  $E_{out2}$  and may be converted into different forms, so that the first law is always observed, that is:  $\frac{dE_{out1}}{dE_{in}} + \frac{dE_{out2}}{dE_{in}} = 1$ .

But because each light packet has a change and therefore has a specific time (see definitions), therefore, the specific

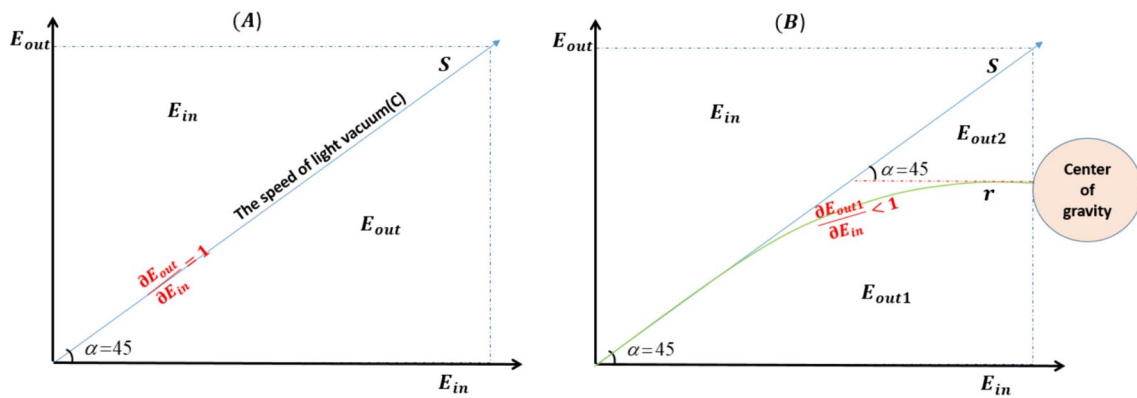
time of light also corresponds to the curved light curve, and in the black hole, where the energy of the light packet goes to zero, the time it has also expanded and the unit of time goes to infinity, as if time has also become zero. For this reason, we believe that there are at least three ways of bending in space: (1) Bending of energy, (2) Bending of energy and time, or (3) Bending of space and time. Figure 14b contains another result, which is that the bending of light is associated with a decrease in its energy change. In other words, the reduction of light energy by the centers of gravity reduces its rate of change, as a result, its speed decreases and leads to the bending of light. This concept is in harmony with the phenomenon of redshift, when the light approaches the center of gravity with decreasing energy, the color of the light goes towards red. In fact, near the centers of gravity, the speed of light slows down from its initial speed, so the momentum of the particle also decreases. In this case, according to Dobroy's equation (Eq. 1), the value of the wavelength of light ( $\lambda$ ) is increased (stretches), as a result, according to the relationship  $t = 9192631770\lambda$ , time dilation occurs and time also stretches (Butto 2020).

As can be seen, Fig. 14b is quite comparable to Figs. 7 and 8, which show the energy curvature and mass curvature in classical physics, respectively.

In space time, the geometrical domain of the particle has received more attention, and usually the Pythagorean relationship is established between the values of  $S$ ,  $r$  and time  $Ct$  (Winter et al. 2017a; Lecca 2021; Michaletti et al. 2017). This is the case for mass and energy in classical physics between  $M_{in}$ ,  $M_{out}$  and  $\nu t$  (Shamohammadi and Shamohammadi 2024).

In kinetic experiments, according to the first law, we are dealing entirely with mass (or entirely with energy), as a result, bending is also discussed based on the bending of the output mass compared to the input mass, but because according to the third law, we can instead Mass (or energy) also uses time, so we can talk about bending masstime or energy time.

The importance of the first, second and third laws is that (1) the equations derived from the above laws are used in the field of mass flow and energy flow in all branches of knowledge (Table 7). (2) The equations derived from the first to third laws are also used for both equilibrium and non-equilibrium states of the system (Figs. 12 and 13). (3) The first law is written in such a way that it is used in open systems (Shamohammadi et al. 2022, 2023a, b, 2024). For this reason, the equations that have been obtained so far based on the mentioned laws (Table 7), first the mass–mass equations were obtained in open or semi-open systems, then using the masstime equivalence law, they were converted into kinetic equations. (Shamohammadi and Shamohammadi 2024). Table 7 shows a number of equations derived from



**Fig. 14** The relationship between the bending of light and the energy output from it in a package of light, **a** input energy and output energy in vacuum, **b** input energy and output energy when the light goes toward the center of gravity

**Table 7** Introduction of equilibrium models in different scientific fields based on the first, second and third laws

Basic Law	Scientific field	Model	References	The present study based on first law, second law and third law (modified models)
The first law and the second law	Water–soil	$i = FC \frac{H}{K_{sh}+H} + kH$	Shamohammadi et al. (2023b)	$i = PWP + R_f \frac{H_l}{K_{sh}+H_l} + kH_l$
	Hydrology(rainfall–runoff)	$S = S_{max} \frac{P_a}{K_{sh}+P_a}$	Shamohammadi et al. (2023a)	$S = I + F_{max} \frac{P_{al}}{K_{sh}+P_{al}}$
	Surface chemistry	$q = q_{max} \frac{C}{K_{sh}+C}$	Shamohammadi et al. (2022)	$q = q_T + q_{emax} \frac{C_l}{K_{sh}+C_l}$
	Chemical kinetics	$x_p = x_{pmax} \frac{C}{K_{sh}+C}$	Shamohammadi et al. (2024)	$x_p = c_T + x_{pmax} \frac{C_l}{K_{sh}+C_l}$
	Motion and energy	$e_{\mu} = e_{\mu ST} + e_{\mu kmax} \frac{E_l}{t_k+E_l}$	Current study	$e_{\mu} = e_{\mu ST} + e_{\mu kmax} \frac{E_l}{K_{sh}+E_l}$
The second law and third law	Water–soil	$I_t = FC \frac{t}{t_k+t} + kt$	Shamohammadi et al. (2024)	$i = PWP + R_f \frac{t_l}{t_k+t_l} + kt_l$
	Hydrology (rainfall–runoff)	$S_t = S_{max} \frac{t}{t_k+t}$	Shamohammadi et al. (2024)	$S = I + F_{max} \frac{t_{al}}{t_k+t_{al}}$
	Surface chemistry	$q_t = q_{max} \frac{t}{t_k+t}$	Shamohammadi and Shamohammadi (2024)	$q = q_T + q_{emax} \frac{t_l}{t_k+t_l}$
	Chemical kinetics	$x_{tp} = x_{pmax} \frac{t}{t_k+t}$	Shamohammadi et al. (2024)	$x_p = c_T + x_{pmax} \frac{t_l}{t_k+t_l}$
	Half-life equation	$x_{tr} = C_0 - x_{pmax} \frac{t}{t_k+t}$	Shamohammadi et al. (2024)	$x_{tr} = C_0 - x_{pmax} \frac{t}{t_k+t}$
Motion and energy	$e_{\mu} = e_{\mu ST} + e_{\mu kmax} \frac{t_l}{t_k+t_l}$	Current study	$e_{\mu} = e_{\mu ST} + e_{\mu kmax} \frac{t_l}{t_k+t_l}$	

the laws mentioned in different branches of knowledge along with their modifications.

As can be seen in Table 7, the first and second terms of all models are the same, only in the water–soil scientific field, because the end of the soil column is open and the experiments were carried out in the field and in the natural open system, and the end of the soil column is has been open, after water–soil balance, the flow of water flows from the end of the soil (drainage), as a result, the  $Kt$  term was added to the infiltration kinetic equation based on the first law. Likewise, in the mass–mass model of the water–soil system, the  $KH$  term has been added (Shamohammadi et al. 2023b). The rest of the models are completely similar.

In rainfall–runoff models, although the statistical data are based on the open system flow, but because the deep infiltration of the soil is neglected, the general form of the

equations is similar to the equations of surface absorption (surface chemistry) and chemical kinetics (organic chemistry field) which Usually obtained by laboratory data.

All models in Table 7 are derivable. As a result, they can cover a wide level of knowledge. Shamohammadi et al. 2023b, by deriving the infiltration equation, presented the equation of water infiltration rate inside the soil and also provided acceptable results.

### Conclusion

- In this study, using new definitions for “phenomenon” and “time”, the relationship between “phenomenon”–“time”–“change” is presented. By introducing these

theoretical foundations, we think the challenge between “being” or “not being” time will be solved.

- It was shown that the three laws of dynamic mass conservation, irreversibility and time–mass (energy) equivalence are able to play a significant role in classical physics as the basis of all models of mass–mass, energy–energy, mass–time and time–energy.
- Based on the aforementioned rules, 11 models were introduced in important scientific branches, all of which have a general form  $M = M_T + M_{emax} \frac{M_{in}}{M_k + M_{in}}$ ,  $E = E_T + E_{emax} \frac{E_{in}}{E_k + E_{in}}$ ,  $M = M_T + M_{emax} \frac{t_{in}}{k_i + t_{in}}$  and  $E = E_T + E_{emax} \frac{t_{in}}{k_i + t_{in}}$  and each of them is able to cover a part of science. Due to the fact that these models are derivable, they can be used on a wide scale.
- In this study, the theory of mass equivalence law was completed with the definition of specific transformation speed, and the time–mass and time–energy equivalence formulas were introduced as  $m = vt$  and  $E = vt$ , respectively. This made the law of equivalence to play a more important role in the development of kinetic models.
- The aforementioned rules made the flood kinetics model, which was raised as an important challenge for many years, to be obtained for the first time and enable us to predict the peak flow of dangerous floods and thus save the lives of thousands of people every year.
- In this study, in addition to comparing time–mass and time–energy curvature with space–time curvature, we showed that it is possible to introduce mass–mass and energy–energy curvature for the first time.
- In this study, it was shown that by carbonizing GWH with N<sub>2</sub> gas and combining it with KOH, it has a great effect on increasing the capacity of GWH and increases its capacity to absorb heavy metals by an average of 1.7 t.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s13201-024-02263-7>.

## Declarations

**Conflict of interest** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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