Here are some passages for you to consider. These are from the Kemp-Smith translation. (This is available online, so I can cut and paste from it.) I have omitted parts of the passage to save space, and to side-step certain interpretive issues. So look at the full text in your books.

These passages begin at A104 (First Edition Transcendental Deduction).

At this point we must make clear to ourselves what we mean by the expression 'an object of representations'. .... It is easily seen that this object must be thought only as something in general = x, since outside our knowledge we have nothing which we could set over against this knowledge as corresponding to it.

Now we find that our thought of the relation of all knowledge to its object carries with it an element of necessity; the object is viewed as that which prevents our modes of knowledge from being haphazard or arbitrary, and which determines them a priori in some definite fashion. For in so far as they are to relate to an object, they must necessarily agree with one another, that is, must possess that unity which constitutes the concept of an object. [Emphases (in all these passages) mine. You think about why I emphasized them!]

But it is clear that, since we have to deal only with the manifold of our representations ... the unity which the object makes necessary can be nothing else than the formal unity of consciousness in the synthesis of the manifold of representations. It is only when we have thus produced synthetic unity in the manifold of intuition that we are in a position to say that we know the object. But this unity is impossible if the intuition cannot be generated in accordance with a rule by means of such a function of synthesis as makes the reproduction of the manifold a priori necessary, and renders possible a concept in which it is united.... This unity of rule determines all the manifold, and limits it to conditions which make unity of apperception possible. The concept of this unity is the representation of the object = x, which I think through the predicates, above mentioned, of a triangle.

So, to understand our representations as being about an object, we must view them (our representations) as being connected according to a necessary rule for how to “unify” representations. The unity which this concept of an object makes possible is the “formal unity of consciousness.”
All necessity, without exception, is grounded in a transcendental condition. There must, therefore, be a transcendental ground of the unity of consciousness in the synthesis of the manifold of all our intuitions, and consequently also of the concepts of objects in general, and so of all objects of experience, a ground without which it would be impossible to think any object for our intuitions; for this object is no more than that something, the concept of which expresses such a necessity of synthesis.

This original and transcendental condition is no other than transcendental apperception. .... To render such a transcendental presupposition valid, there must be a condition which precedes all experience, and which makes experience itself possible.

We saw above that, in order to count as (constituting) representations of objects, our representations must be connected by a necessary rule for unifying them. The “unity” of this rule makes possible the “formal unity of consciousness.” In the next passage, we see that there must be a “transcendental ground” of this necessity. This transcendental ground or “condition” is then labeled “transcendental apperception.”

There can be in us no modes of knowledge, no connection or unity of one mode of knowledge with another, without that unity of consciousness which precedes all data of intuitions, and by relation to which representation of objects is alone possible. This pure original unchangeable consciousness I shall name transcendental apperception.

This transcendental ground, called “transcendental apperception,” is now described as a “unity of consciousness” and as a “pure original unchangeable consciousness.”

There are lots of questions that can be asked about this “transcendental apperception.” It is described as a unity, as a single thing. But what is this “unity?” Is Kant’s claim that to be representations of an object, all these representations must “in” a single “mental container,” i.e., parts of one “transcendent mind” or “self-in-itself?” (Note I used the phrase “transcendent” mind, while Kant is talking about the unity of something “transcendental.” That is a hint as to my answer the question just asked.)

Kant continues:
This transcendental unity of apperception forms out of all possible appearances, which can stand alongside one another in one experience, a connection of all these representations according to laws. For this unity of consciousness would be impossible if the mind in knowledge of the manifold could not become conscious of the identity of function whereby it synthetically combines it in one knowledge. The original and necessary consciousness of the identity of the self is thus at the same time a consciousness of an equally necessary unity of the synthesis of all appearances according to ... rules, which ... determine an object for their intuition, that is, the concept of something wherein they are necessarily interconnected. For the mind could never think its identity in the manifoldness of its representations, and indeed think this identity a priori, if it did not have before its eyes the identity of its act, whereby it subordinates all synthesis of apprehension (which is empirical) to a transcendental unity, thereby rendering possible their interconnection according to a priori rules.

I take this to mean that the necessary “unity” Kant calls “transcendental apperception” is the not the numerical unity of some “mind-in-itself” in which all these representations must be contained, but the unity of “function” by which it unifies these representations. What’s more, my awareness (or my potential awareness, as he will make clear in the B edition) of myself as a single subject of conscious experience would be impossible without the (potential) awareness of the unity of the rule of “object-hood” by which I synthesize a manifold of intuition into cognition of an object.

If you will, subjective identity both pre-supposes, and is pre-supposed by, objective uniformity. I think that this is what the following says:

Since this unity must be regarded as necessary a priori ... the objective reality of our empirical knowledge, rests on the transcendental law, that all appearances ... must stand under those a priori rules of synthetical unity whereby the interrelating of these appearances in empirical intuition is alone possible. In other words, appearances in experience must stand under the conditions of the necessary unity of apperception, just as in mere intuition they must be subject to the formal conditions of space and of time. Only thus can any knowledge become possible at all.

So, this necessary unity of transcendental apperception leads to the possibility of synthetic a priori knowledge of appearances.

Now consider:
There is one single experience in which all perceptions are represented as in thoroughgoing and orderly connection, just as there is only one space and one time in which all modes of appearance and all relation of being or not being occur. When we speak of different experiences, we can refer only to the various perceptions, all of which, as such, belong to one and the same general experience. This thoroughgoing synthetic unity of perceptions is indeed the form of experience; it is nothing else than the synthetic unity of appearances in accordance with concepts.

Hmmm..... “One single experience?” Many, many time, I have asked myself, “Which one?” Hint: that wasn’t a helpful question.

Kant continues:

**The a priori conditions of a possible experience in general are at the same time conditions of the possibility of objects of experience.** Now I maintain that the categories, above cited, are nothing but the conditions of thought in a possible experience, just as space and time are the conditions of intuition for that same experience. They are fundamental concepts by which we think objects in general for appearances, and have therefore a priori objective validity. This is exactly what we desired to prove.

This may not help much yet. But he seems to be claiming that these rules for the synthesis of representations into cognition of an object are “a priori conditions for the possibility of experience.”

One last quote from this section, at A123, which I will simply leave for your consideration:

The objective unity of all empirical consciousness in one consciousness, that of original apperception, is thus the necessary condition of all possible perception; and [this being recognized we can prove that] the affinity of all appearances, near or remote, is a necessary consequence of a synthesis in imagination which is grounded a priori on rules.

So, the unity of transcendental apperception is the necessary condition for the “affinity of all appearances, near or remote ....”

Towards the beginning of the B edition, we find the following, oft-quoted passage:

It must be possible for the 'I think' to accompany all my representations; for otherwise something would be represented in me which could not be
thought at all, and that is equivalent to saying that the representation would be impossible, or at least would be nothing to me. ... [T]his representation is an act of spontaneity, that is, it cannot be regarded as belonging to sensibility. I call it pure apperception ... because it is that self-consciousness which ... must be capable of accompanying all other representations, and which in all consciousness is one and the same.... The unity of this apperception I likewise entitle the transcendental unity of self-consciousness, in order to indicate the possibility of a priori knowledge arising from it. For the manifold representations, which are given in an intuition, would not be one and all my representations, if they did not all belong to one self-consciousness. As my representations (even if I am not conscious of them as such) they must conform to the condition under which alone they can stand together in one universal self-consciousness, because otherwise they would not all without exception belong to me. From this original combination many consequences follow.

Once again, it sounds like the “unity” he is talking about here is the unity of “box” in which all my representation must occur in order for them all to be my representations. I have already indicated I think that is not what he is saying.

This thoroughgoing identity of the apperception of a manifold which is given in intuition contains a synthesis of representations, and is possible only through the consciousness of this synthesis. .... Only in so far, therefore, as I can unite a manifold of given representations in one consciousness, is it possible for me to represent to myself the identity of the consciousness in [i.e. throughout] these representations. In other words, the analytic unity of apperception is possible only under the presupposition of a certain synthetic unity.

Now, what is this “one consciousness?” My remarks above have already indicated the direction of my answer. The metaphysical identity or unity of my mind-in-itself is not something, for Kant, that I can know anything about. So it would be problematic were he claiming that a consciousness could never happen unless self-identical mind-in-itself did certain sorts of things, or collected certain things inside itself. According to Kant, I know myself, like I know everything else, only as appearing. So, I can’t really know that I have a numerically identically self-in-itself synthesizing all these representations. And that, in a way, is the point: the identity or unity that Kant is talking about here is a unity within consciousness, not the unity of some hypothesized entity that is consciousness happens “in.”
Finally, as to the “one experience” passage, I will leave you to think about this. But, I think, the unity of function by means of which I must unite representations must translate into the unity of the \textit{a priori} laws that objects must be experienced as standing in.

Consciousness of unity (necessary for cognition of objects) requires (potential consciousness of the) unity of consciousness. But the only unity of consciousness (immanent within consciousness of objects) is the unity of the “rule” by which I synthesize the manifold of intuition into cognition of objects. \textit{A priori} knowledge of what we call “laws of nature” is possible only because these laws stem from the necessary conditions for the possibility of experience. So, this unity of the rules for synthesis of a manifold into cognition of objects produces a unity of “laws of nature” that I can know \textit{a priori} must apply to appearances.

So, I claim, this unity of self that Kant call the transcendental unity of apperception, makes itself manifest as the unity of world we experience, the unity of nature, i.e., the unity of laws of nature, or, finally, as the unity of science. Empirical objects that did not conform to the same laws of nature would be objects cognized through a different synthesizing function, i.e., by a numerically distinct transcendental apperception. That is, they would not be objects in my world. From “one single experience” we arrive at “one single nature!”