How Does Matter Hold Itself Together?

Physicists recognize four basic forces:

Gravity between masses

Electric between electric charges

Weak nuclear force between electrons and nucleons (protons and neutrons)

Strong nuclear force between nucleons (and related particles)

We think of gravity as being very strong, but it only seems that way because all masses attract, and the larger the mass, the stronger is the apparent gravitational force. Electric forces come from charges that can attract and can repel. Also, matter of normal size tends to have very nearly balanced positive and negative charges so that the net electric force is nearly canceled. The nuclear forces are short range and have little attraction beyond a few femptometers (10^{-15} m).

When we talk about the forces between molecules or within molecules, we are dealing with electric forces and can ignore gravity and nuclear forces.

When we talk about nuclei and their reactions, we are dealing primarily with the two nuclear forces and can ignore gravity and to a large extent can also ignore electric forces. Changes in nuclear energy levels produce gamma rays with energies that are about 300 times more energetic than photons from atomic electron configuration changes. By contrast, the photons from molecular energy changes are typically 10 times weaker than the atomic configuration changes.

Chemistry is about atoms retaining their identity, but exchanging or sharing their outermost electrons. Their electric forces can bind atoms together into molecules, atoms together into crystals, and molecules together into still larger structures.

This chemical binding is roughly classified as follows:

Ionic binding where electrons from some atoms are stolen by other atoms. That resulting atoms then have opposite charges which leads to an attractive force between them. This is usually between the metals in the two leftmost columns of the Periodic Table which are happy to give up their one or two outermost atoms and the atoms F, Cl, Br, I, and O which like to steal electrons.

Covalent bonding where electrons are shared by a small number of atoms, often but not always equally. This is common among H, C, N, O, P, S, and a few others. Some covalent bonds, like in water molecules, have their oxygen atoms hogging the shared electrons. This can produce a dipole moment that affects how the molecule interacts with other molecules.

Metallic bonding where some of the outermost electrons are shared among all atoms of a crystal. This allows the material to conduct electricity. Metals are partly held together by those electrons.

Hydrogen bonding where weak forces appear between molecules. Ice, DNA, and many polymer sheets are held together by hydrogen bonds.