Question 1:

Dear Cheap Astronomy – How long did the Universe take to complete the periodic table?

So, this is really a question about nucleosynthesis, which began with the Big Bang and continues today in stars – and on a small scale in human-built laboratories. The periodic table has grown over the lifetime of the Universe. Within the first 3 minutes nearly all of the Universe's hydrogen content and most of its helium were formed, the hydrogen coming first but much of it fusing into helium those early moments where the whole universe was still small and dense and very hot. Some lithium and beryllium, maybe even traces of boron and carbon were also produced at that time. Then not much happened until 200 million years later when the first stars formed. Those early stars were mostly big ones, fusing hydrogen to add yet more helium to the Universe within their stellar wind, but at the same time they were also fusing new elements around their core – where an outer shell of helium was compressed down on a shell of nitrogen, compressed down on a shell of carbon and neon, then a shell of oxygen and carbon, then a shell of silicon and sulfur and finally an iron-nickel core. Fusion continued above and between those shells of new elements, the centre becoming ever hotter and denser until the iron-nickel core eventually collapsed into degenerate matter and the sudden in-falling of all the surrounding material adds kinetic energy to the mix, drove a new level of even-more energetic fusion reactions, releasing so much energy that the star blows itself to bits. For really big stars this may mean complete annihilation, while for moderately big stars a remnant black hole is left behind and for just averagely big stars a neutron star is left behind. The rest of original star's mass including a rich mix of new elements, is blown outwards to seed the cosmos.

There's a few caveats though… Nearly all the iron and nickel formed in the core of a big star is destroyed in the core collapse, so any iron and nickel those stars donate to the Universe is newly formed in their supernova explosion. In fact, most of the iron and nickel in the Universe comes from exploding white dwarves – that is, Type 1a supernovae. White dwarves are formed at the end of the life of a modestly-large star like our Sun and are always less 1.44 solar masses, but if it later takes on more mass – usually drawn from a binary companion, and it exceeds 1.44 solar masses, the Chandrasehkar limit, then kablooie. White dwarves are mostly carbon and oxygen, but the extra mass addition drives lots of sudden new fusion, which blows the star to bits, so seeding the cosmos with yet more elements.

The main contributor to the Universe's really heavy elements, including gold and uranium, is something else again. A neutron star, colliding with either another neutron star or a black hole creates a kilonova – which is not as bright as a supernova, but still a thousand times brighter than a nova. The collision creates lot of new fusion events, creating lots of new energy that blows the neutron stars to bits and since they are the densest visible objects in the Universe, their post-collision fusion products include the heaviest naturally occurring elements in the Universe.

So, most of the periodic table comes from stellar explosions. Nonetheless, a lot of elements including quite heavy elements form inside small stars like the Sun and are later shrugged off into the cosmos when that star goes red giant towards the end of its billions-of-years long life. For example, this is where most of the universe's lead comes from, even though some lead does comes from stellar explosions too.

But anyway, how long did it take to complete the periodic table? The first stars appeared 200 million years after the big bang. Really big stars can form and explode is less than a million years, but the modestly-large ones likely to leave a neutron star behind have lifetimes more like 10 million years. We can only guess at the likelihood of two neutron stars colliding as their orbits decay, but maybe by the end of the Universe's first half billion years, the first Uranium had formed from a neutron star collision along with lots of other heavy elements. That probably introduced all the elements we have today, but their current abundances are also influenced by smaller stars evolving through their lifespans, which are measured in billions of years, around ten billion in the case of the Sun.

Question 2:

Dear Cheap Astronomy – Is Interstellar travel really out of the question?

Our current understanding of physics suggests that travelling to the nearest star within a human life time is pretty much out of the question. Regardless of what type of engine you use – even approaching, let alone passing the speed of light puts you at risk of destroying your spaceship through collisions with just specks of cosmic dust. You could design some kind of deflector device to clear the way ahead of you, but anything using electromagnetic principles can only deflect charged particles so you'd still need impact shielding to deflect any neutrally-charged particles. So, you could try flying with some kind of multi layered shield positioned in front of you, which has huge shock absorbers built into it.

But even with your shock-absorbing shield working at sub-light speed, you'll still have a problem with drag. Every time you deflect a particle out of your path, either electromagnetically or with an impact shield, that deflection will decelerate you slightly – an effect that becomes more significant the faster you go. One traditional interstellar spacecraft design, the Bussard ramjet, is a good illustration of the drag problem. The ramjet envisions a spacecraft with a massive scoop in front, the scoop having a diameter measured in kilometres, its role being to scoop up hydrogen ions as it goes forward, collecting and concentrating them into a drive chamber, where they are accelerated up to high speed and then shot out of the back. So the spacecraft gains propulsion without having to carry its own propellant.

Trouble is every particle scooped up represents a tiny impact and a tiny deceleration. It's been calculated that once you get to around 12% of light speed, the benefit gained by accelerating the particles out the back is fully countered by the decelerating drag of the scoop up the front. So you reach a terminal velocity and just can't go faster. 12% light speed is still pretty fast of course, so assuming you can build some sort of hydrogen collection fusion accelerating engine, this really could be an interstellar spacecraft – although you won't make it to other stars within a human lifetime.

Of course a streamlined spacecraft with an internal propulsion drive, just needs deflectors and impact shielding – and without the huge scoop out the front it should experience less net drag. But, one isolated impact with a dust grain at 99% of the speed of light is still going to be a heck of a jolt – remembering that kinetic energy equals one half MV squared. So, it's not so much the mass of the object, but the speed you hit it at that matters.

Anyway, apart from the Bussard ramjet, other interstellar drive concepts each have their own pro and cons. Firstly, warp drive – meh, probably impossible, the Alcubierre drive/warp bubble is interesting, but way beyond being technically feasible with our current understanding of physics. The various reactionless drive concepts, the EM drive and all that, just plain don't work. You can't achieve a sustained momentum gain by just moving matter or microwaves around in your spacecraft – and no amount of quantum or relativistic hand waving will help, it's just bad physics. You either need to push something out the back of your spacecraft or be pushed forward by something. So you either need a propulsion system, essentially a rocket, or you can be pushed forward by starlight or by laser light – or you can drop nuclear bombs out the back so as to get pushed forward by their blasts.

But beyond all the technology challenges, if you can't get anywhere much within your lifetime, what exactly is the point? Sure you can start a multi-generational crew so that your distant progeny go places – but are you sure your kids or your grandkids will thank you for that? And even if those individuals do arrive somewhere long after your death why does that matter to you? So, why not just send robots who can report back to your kids and your grandkids as they live out their lives comfortably back here on Earth. Robots don't have all the problems involved in life support, nor will they end up hating you for what you did to them. Here at Cheap Astronomy the answer to most of life's problems is robots.