Momentum and Ion Rockets

An "ion rocket" uses ions of any element, accelerated by a high voltage, in place of the exhaust gases from burning fuel in the conventional way. The thrust is small, but can be applied for a long time; years if necessary.

NASA's Glenn Deep Space-1 mission, launched in 1998, was an experimental satellite which used a Xenon ion propulsion engine. The data in this question comes from the NASA website*.

1) In the Ion Engine, singly-ionised Xenon atoms (Xe^+) were accelerated across a potential difference of 1280V. How much energy does each ion gain, in Joules?

2) Calculate the speed gain of the ion.
(RAM of Xenon = 131 and 1 AMU = 1.66×10^{-27} kg)

3) Calculate the gain of momentum of a single ion, assuming it starts from rest.

4) This gain of momentum of the Xenon ions equals the gain of momentum (in the opposite direction) of the rocket from which they were ejected.
Use *Force = rate of change of momentum* to calculate the Force on the rocket if it uses 100g of Xe every day.

5) NASA's website claims the maximum thrust available from the engine was 92mN and the minimum was 20mN. Does this fit with your answer to q4?

6) The mass of the satellite was 490 kg. Calculate its acceleration, using the force you calculated in q4.

The Deep Space-1 satellite moved around the inner solar system, testing the engine and encountering a few comets. It used 72kg of Xenon overall. However, would it be feasible to use the same system to send a satellite to investigate other solar systems?

7) How long would 72kg of fuel last if used at the rate of 100g per day?

8) If it accelerated at the rate calculated in q6, how fast would it be moving after this time?

9) Assuming a constant rate of acceleration, what distance would it travel in this time? Express your answer in AU (1 AU = 150 million km).

10) At the speed calculated in q8, how long (in years) would it take the satellite to reach the nearest star to Earth (distance = 4.2 ly)?

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* www.nasa.gov/centers/glenn/about/history/ds1.html