Asteroids (in space) and Meteorites (once they have entered the atmosphere)

Meteorites hit the atmosphere with speeds from 12 to 72 km/s.
Earth's orbital speed is 30 km/s and the escape speed from the solar system at the Earth is 42 km/s

Q: draw a diagram and use it to show why the maximum speed is 72 km/s

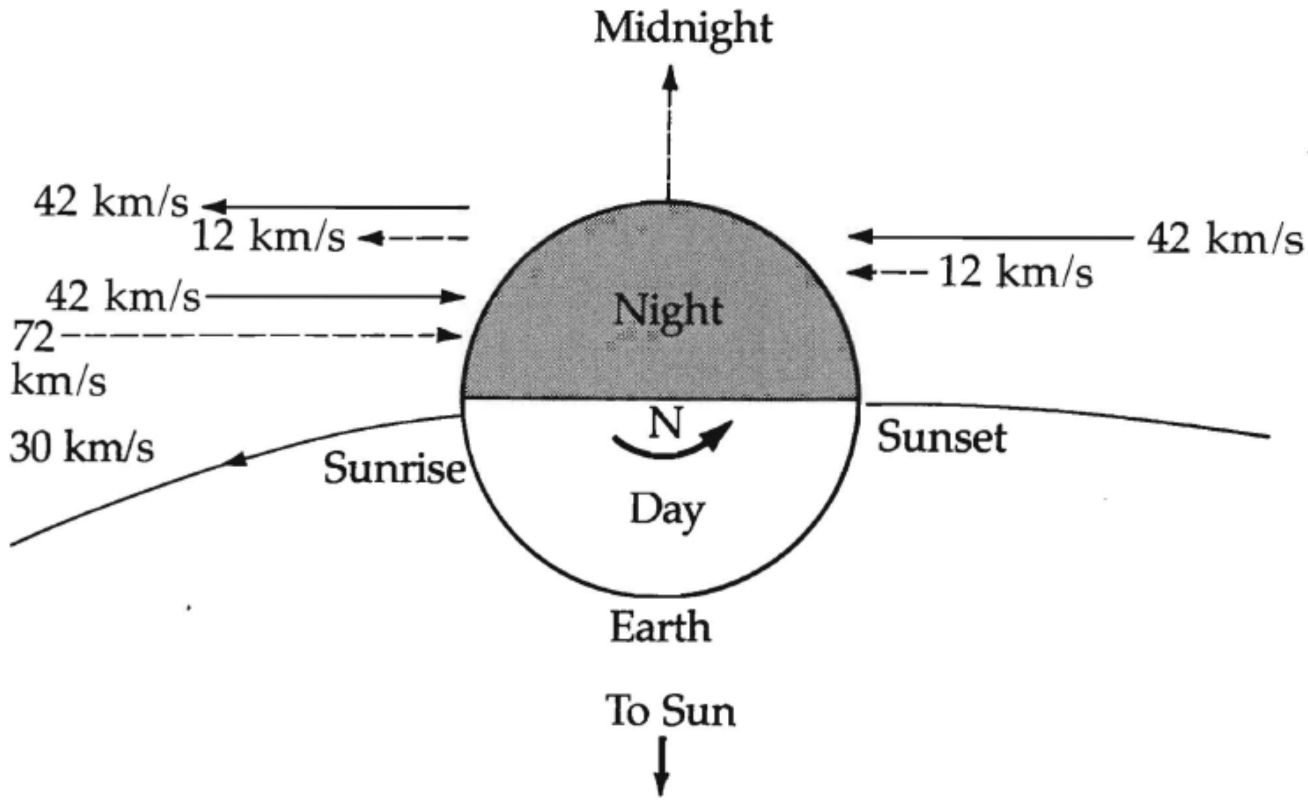


Figure 7–25 Meteor speeds. The solar escape velocity at the Earth's orbit is 42 km/s; meteoroids cannot move faster than this speed. In early evening, meteors catch up to the Earth. After midnight, the Earth (orbital speed 30 km/s) catches up to all but the fastest meteoroids moving along its orbit.

Only asteroids which are large enough will survive burn-up in the Earth’s atmosphere and land as meteorites

Types:

- Irons
- Stones (light silicates, like Earth’s crust)
- Stony Irons (show small stony bits set in Fe)

Iron meteorites can show large crystalline patterns: Widmanstatten patterns

In order to form these large crystals, the metal has to cool extremely slowly: 1 degree per million years

Metal would cool much more quickly in space; it must have been protected by a large body of 10 km or more in diameter

Differentiation

Asteroid forms, is homogeneous

Heated by radioactive decay, melts

Dense material falls to the center (cf Earth's core)

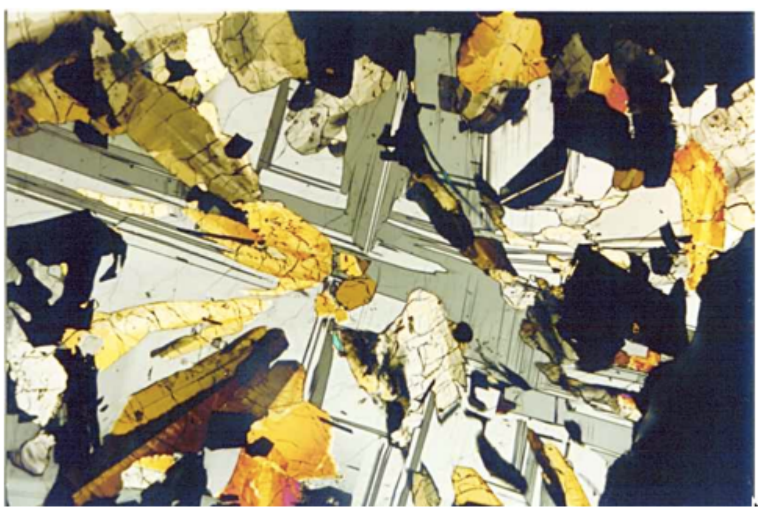
Since the short-lived radionuclides are long gone, this suggests that these asteroids were formed in the early solar system

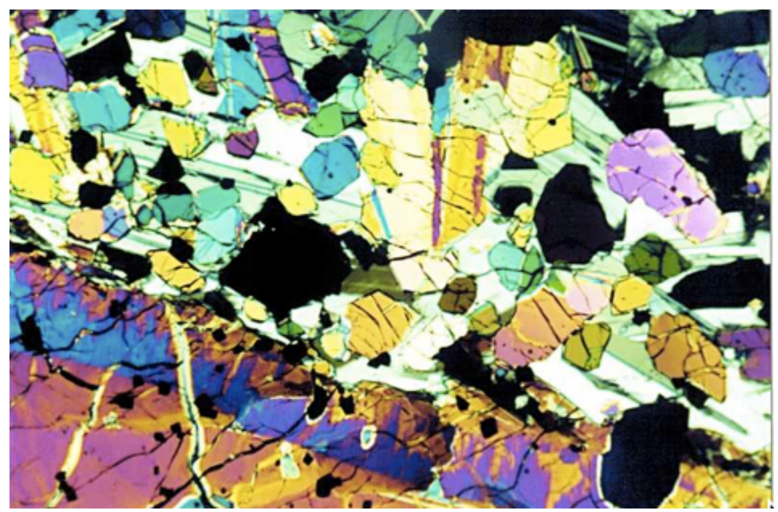
Age-dating of meteorites supports this: all very old (4-5 billion years)

Meteorites are samples of the early solar system

Some meteorites actually came from the Moon or Mars

Q: how did they make their way to Earth?





Photomicrographs of thin sections of Moon rocks

Age-dating rocks

What do we mean by the age of the rock?

Generally, time rock has existed without being chemically disturbed

Consider parent, daughter isotopes,
(P, D) where parent isotope P
decays into daughter isotope D

For solar system dating we use long-lived radioactive isotope pairs like (^{40}K, ^{40}Ar)

(^{87}Rb, ^{87}Sr)

(^{238}U, ^{238}Pb) — 238: no of protons + neutrons

$P(t)$ $D(t)$ are # of atoms of P and D at time t.

Between t and $t+dt$,

$dD(t)$ atoms of D appear

$dP(t)$ atoms of P disappear

$$dD(t) = -dP(t) = \lambda P(t)\,dt$$

λ is radioactive decay constant

$$dP(t) = -\lambda P(t)\, dt$$

$$\frac{dP}{P} = -\lambda\, dt$$

Integrate from 0 to t ($P(0)$ to $P(t)$)

$$\int_{P(0)}^{P(t)} \frac{dP}{P} = -\lambda \int_0^t dt$$

$$\left[\ln P \right]_{P(0)}^{P(t)} = -\lambda \left[t \right]_0^t$$

$$\ln\left(\frac{P(t)}{P(0)}\right) = -\lambda t$$

$$\frac{P(t)}{P(0)} = e^{-\lambda t}$$

$$P(t) = P(0)\, e^{-\lambda t}$$

Similarly

$$D(t) = D(0) + P(0)\left(1 - e^{-\lambda t}\right)$$

Q We know the decay constant for the decay of ^{87}Rb to ^{87}Sr (1.4×10^{-11}/yr)

Why can't we just measure the amount of ^{87}Rb and of ^{87}Sr & use the above equations to derive the age of the rock?

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This will only work if there was NO ^{87}Sr in the ~~3~~ rock when it formed.

Stony meteorites are chemically heterogeneous

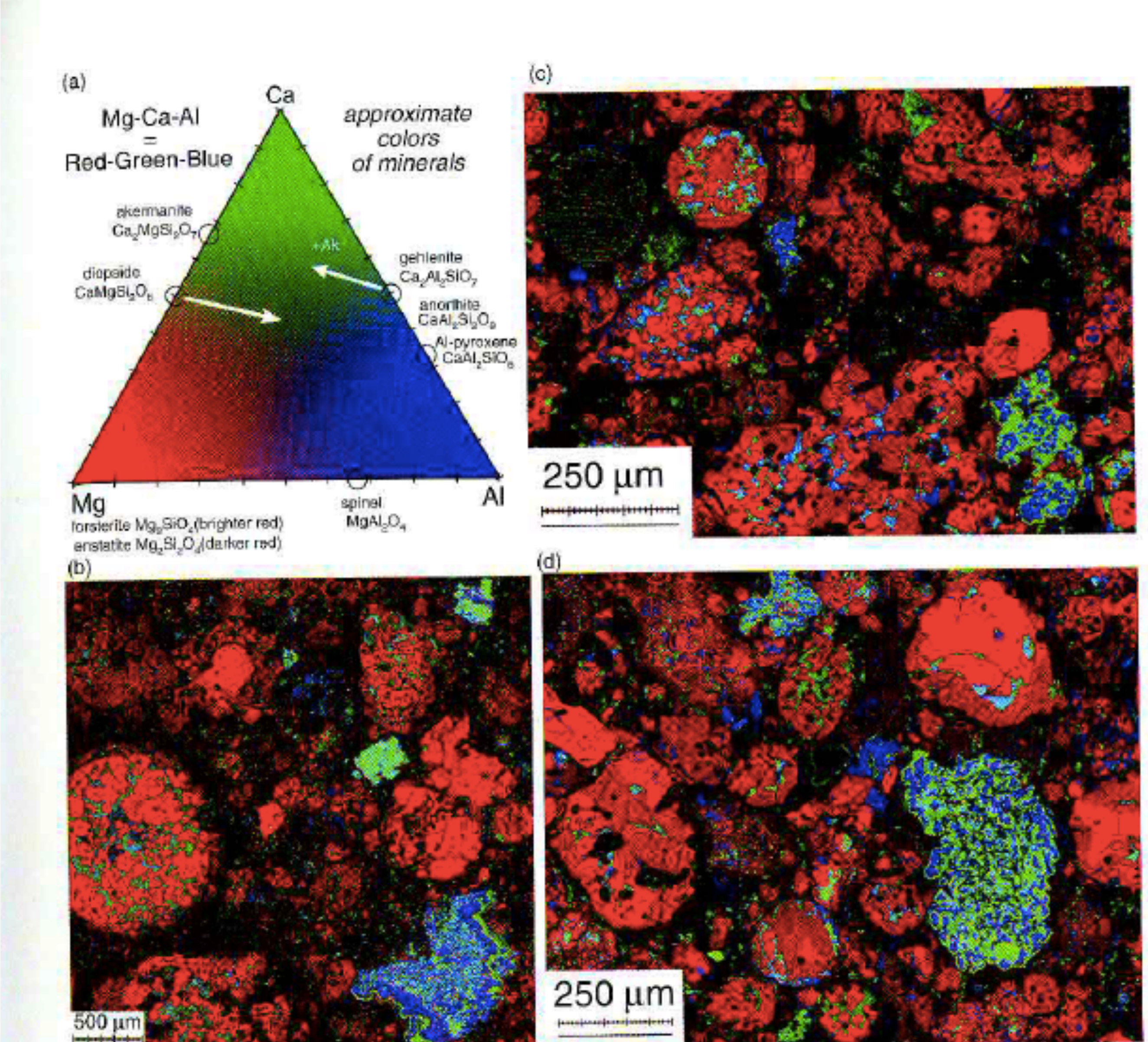


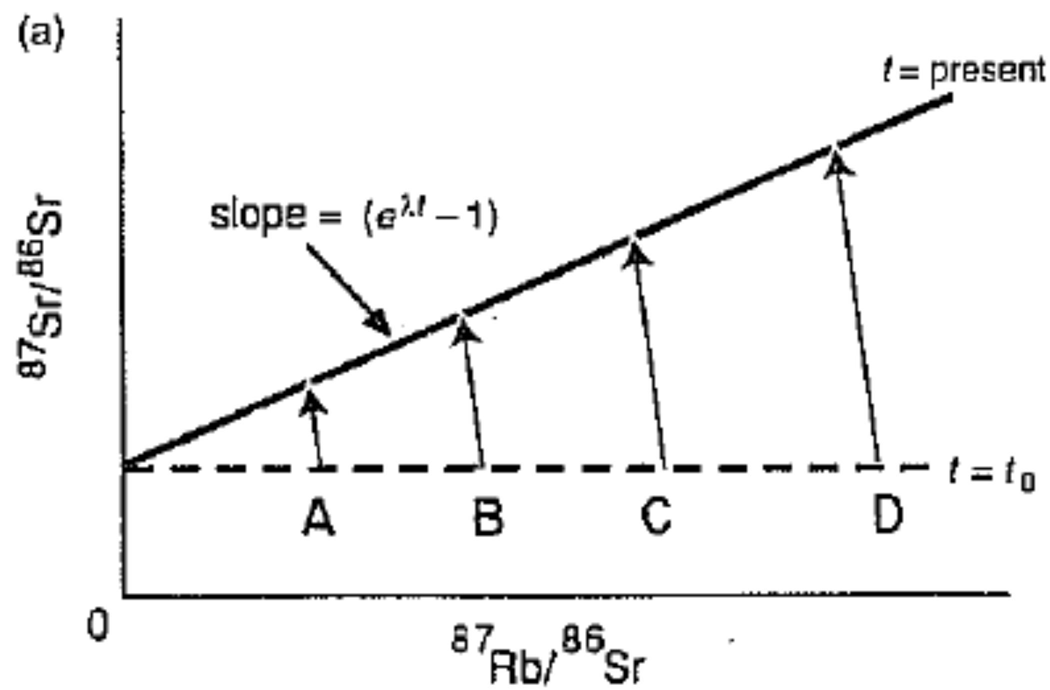
Figure 8.17

The way around this is to also look at a stable isotope of the daughter element, S

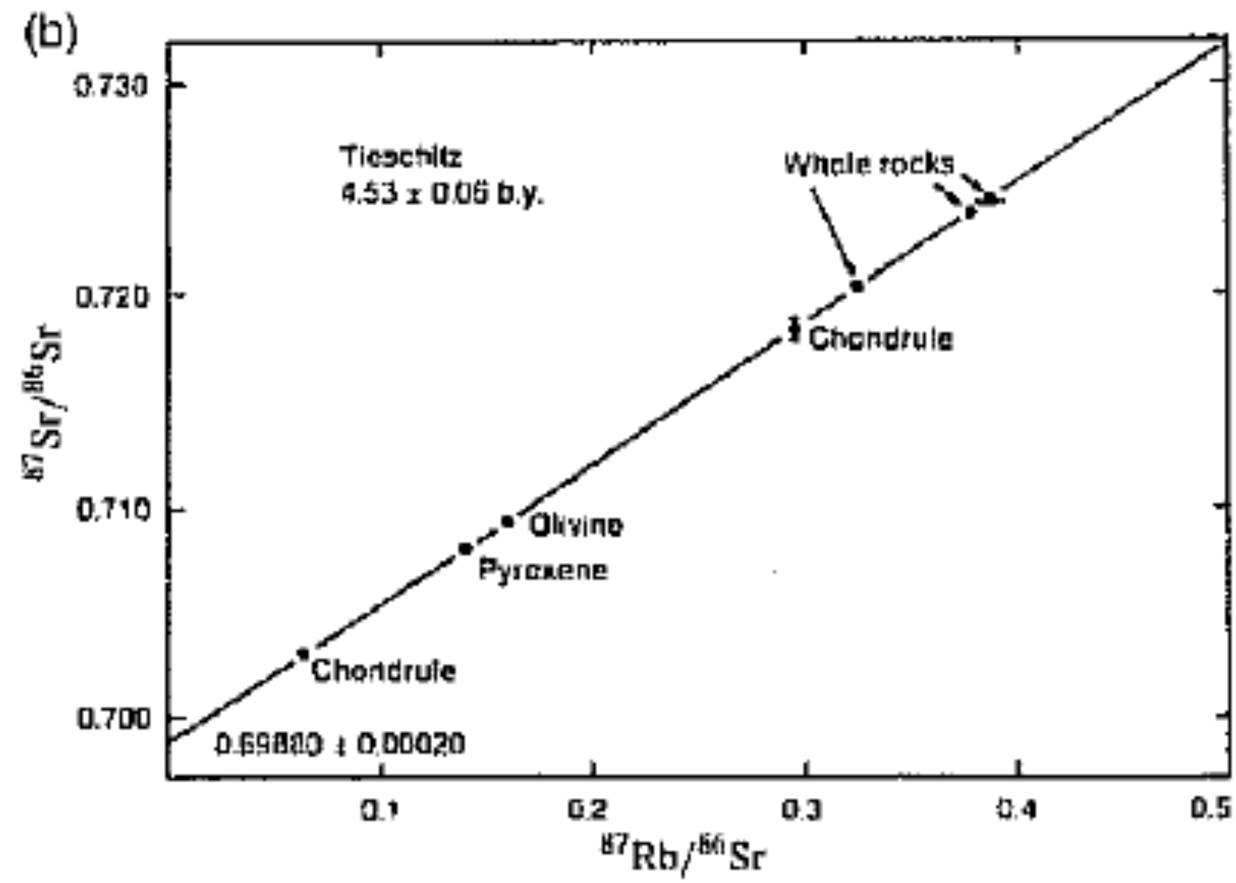
Any chemical processes affect both isotopes of the daughter the same. So we would expect the ratio $D(0)/S(0)$ to be the same in different bits of rock

$$\frac{D(t)}{S(t)} = \frac{D(0)}{S(0)} + \left(e^{\lambda t} - 1\right)\frac{P(t)}{S(t)}$$

Sr isotope ratio: daughter(87)/ stable (86) isotope



Parent / stable isotope of Sr



$^{87}Rb/^{87}Sr$ isochron for the Tieschlitz H3 chondrite meteorite