2003 Part II Q1B Exp

Probes:

a) Method 1) Compare ion saturation currents: $I_{is} = 0.6\, q n A \sqrt{\frac{T_e}{m_i}}$

$$\frac{I_{isH}}{I_{isU}} = \sqrt{\frac{m_U}{m_H}} = \sqrt{238} \simeq 15.4$$ ← very accurate; easy to distinguish the plasmas

Method 2) Measure $V_p - V_f$ (V_p using emitting probe)

$$\Rightarrow 0.6\, enA \sqrt{\frac{T_e}{m_i}} = enA \sqrt{\frac{T_e}{2\pi m_e}} \exp\left(\frac{-e(V_p - V_f)}{T_e}\right)$$

$$\ln\left(0.6 \sqrt{\frac{2\pi m_e}{m_i}}\right) = -\frac{e}{T_e}(V_p - V_f)$$

$$V_p - V_f = \frac{T_e}{e} \ln\left(\frac{1}{0.6}\sqrt{\frac{m_i}{2\pi m_e}}\right) = \frac{T_e}{e}\left[\frac{1}{2}\ln\frac{m_i}{m_e} - \ln\left(0.6\sqrt{2\pi}\right)\right]$$

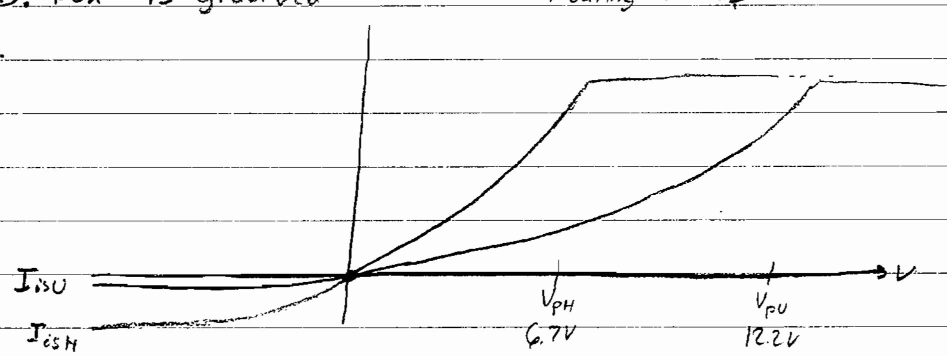
$$V_p - V_f = \frac{T_e}{e}\left[\frac{1}{2}\ln\frac{m_i}{m_p} + 3.35\right]$$

$$V_p - V_f = 2 \cdot \left[3.35\right] = 6.7\text{ V}$$ for hydrogen

$$V_p - V_f = 2 \cdot \left[2.74 + 3.35\right] = 12.2\text{ V}$$ for U238

- only a factor of 2 in voltage; less than $3\,T_e$; not as good accuracy as other method

b. Box is grounded → box is floating → $V_f \equiv 0$



C. T_e to ± 1 eV, H, D, or ^{4}He

Then $\frac{\delta T_e}{T_e} = \frac{\delta m_i}{m_i}$

$\frac{1 eV}{2 eV} = \frac{1 amu}{2 amu}$

→ Uncertainty in T_e means we can't identify the species.

However, we could still distinguish between the H and D plasmas, because $\frac{\delta m_i}{m_H} >> \frac{\delta T_e}{T_e}$: the effect of the mass difference is much greater than the effect from temperature uncertainty.

Plasma Diagnostics: Ion temperature

1) Charge-Exchange Spectroscopy: $H^0 + A^{Z+} \rightarrow H^+ + A^{*(Z-1)+}$

impurity ion radiates. Doppler broadening tells you the temperature

+ Local measurement: beamline crossed with sightline. Also good time resolution
+ radiation is at convenient wavelengths (often visible to near UV)
- must use a neutral beam
- you get impurity ion temperature, which you assume is the bulk ion temp.

2) Neutron spectroscopy: The energy of fusion neutrons is Doppler broadened by the ion temperature. Can measure T_i from the broadening

- Need fusion neutrons!
- Very difficult, not localized
+ T_i of the bulk species

3) X-rays: high Z impurities are not fully stripped (e.g. iron).

From natural line radiation, T_i can be inferred from Doppler broadening

- Need high x-ray detector resolution
- Impurity measurement