ANSWERS TO THEORETICAL PROBLEMS

PROBLEM 1.

1.

$$^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$$
$$^{222}_{88}\mathrm{Rn} \rightarrow {}^{218}_{84}\mathrm{Po} + {}^{4}_{2}\mathrm{He}$$
$$^{218}_{84}\mathrm{Po} \rightarrow {}^{214}_{82}\mathrm{Pb} + {}^{4}_{2}\mathrm{He}$$
$$^{214}_{82}\mathrm{Pb} \rightarrow {}^{214}_{83}\mathrm{Bi} + \mathrm{e}$$
$$^{214}_{83}\mathrm{Bi} \rightarrow {}^{214}_{84}\mathrm{Po} + \mathrm{e}$$
$$^{214}_{84}\mathrm{Po} \rightarrow {}^{210}_{82}\mathrm{Pb} + {}^{4}_{2}\mathrm{He}$$

2. a) If we assume that half-lives of all radium decay products, except those of RaD and Po, are negligible compared to the time of experiment, 83 days, then all radon atoms formed from radium atoms decay (this assumption introduces an error of about 5%). Therefore, each decayed radium atom gives four α-particles.

b) The approximate total number of helium atoms formed during the experiment:

$$N_{\mathrm{He}} = 4xmt = 4\cdot(3.42\cdot10^{10})\cdot0.192\cdot(83.0\cdot24\cdot3600) = 1.88\cdot10^{17}$$

3.

$$N_{\mathrm{A}} = \frac{N_{\mathrm{He}}}{\nu_{\mathrm{He}}} = \frac{1.88\cdot10^{17}}{\dfrac{6.58\cdot10^{-6}}{22.4}} = 6.40\cdot10^{23}\ \mathrm{mol}^{-1}$$

4. The number of radon atoms reaches a quasi-stationary state, which is otherwise called *the radioactive equilibrium*. The correct graph is **C**.

5. The rate of formation of α-particles increases during the experiment, because first they are emitted by radium atoms only and later – by decay products also. The correct graph is **F**.

6. a) In the quasi-stationary state, the rate of radon formation is equal to the rate of its decay:

$$k_1\, N_{\mathrm{Ra}} = k_2\, N'_{\mathrm{Rn}}$$

whence

$$N'_{\mathrm{Rn}} = k_1\, N_{\mathrm{Ra}} / k_2$$

b) The rate constant of radioactive decay is related to half-live:

$$k = \ln 2 / t_{1/2}$$

The rate of radon formation is:

$$k_1\, N_{\mathrm{Ra}} = xm$$

whence

$$N'_{\mathrm{Rn}} = xmT_{1/2}(\mathrm{Rn}) / \ln 2 = (3.42\cdot10^{10})\cdot0.192\cdot(3.83\cdot24\cdot3600) / \ln 2 = 3.14\cdot10^{15}$$

7. During radon decay to RaD 3 α-particles are formed, hence, the total number of helium atoms that could be formed from radon atoms remaining at the end of experiment

$$N'_{He} = 3N_{Rn} = 3 \cdot 3.14 \cdot 10^{15} = 9.42 \cdot 10^{15}.$$

8. a) A more accurate estimate of the number of helium atoms:

$$N_{He} = 4xmt - N'_{He} = 1.88 \cdot 10^{17} - 9.42 \cdot 10^{15} = 1.79 \cdot 10^{17}.$$

b) A more accurate estimate of the Avogadro's number:

$$N_A = \frac{N_{He}}{\nu_{He}} = \frac{1.79 \cdot 10^{17}}{\frac{6.58 \cdot 10^{-6}}{22.4}} = 6.09 \cdot 10^{23}\ \text{mol}^{-1}.$$