AP Chemistry Equilibrium Question

A 40.0 gram sample of solid ammonium carbonate is placed in a closed, evacuated 3.00 liter flask and heated to 400°C. It decomposes to produce ammonia, water vapor, and carbon dioxide according to the following equation:

$$(NH_4)_2CO_3(s) \rightleftharpoons 2\,NH_3(g) + H_2O(g) + CO_2(g)$$

The equilibrium constant, K_p, for the reaction is 0.295 at 400°C.

a) Write the K_p equilibrium constant expression for the reaction.

$$K_p = (P_{NH_3})^2 (P_{H_2O})(P_{CO_2})$$

b) Calculate K_c at 400°C. $K_p = K_c(RT)^{\Delta n}$

$$K_c = \frac{K_p}{(RT)^{\Delta n}} = \frac{0.295}{[(0.0821)(673\text{ K})]^4} = 3.17\times10^{-8}$$

c) Calculate the partial pressure of $NH_3(g)$ at equilibrium at 400°C.

(atm)	$(NH_4)_2CO_3(s)$ ⇄	$2NH_3(g)$ +	$H_2O(g)$ +	$CO_2(g)$
I		0	0	0
C		+2x	+x	+x
E		2x	x	x

$0.295 = (2x)^2(x)(x)$

$0.295 = 4x^4$

$x = 0.521$

$P_{NH_3} = 2x = 2(0.521) = 1.04\text{ atm}$

d) Calculate the total pressure inside the flask at equilibrium.

$P_{TOTAL} = P_{NH_3} + P_{H_2O} + P_{CO_2}$

$P_{TOTAL} = 1.04\text{ atm} + 0.521\text{ atm} + 0.521\text{ atm} = 2.08\text{ atm}$

e) Calculate the number of grams of solid ammonium carbonate in the flask at equilibrium.

FIRST, CALCULATE MOLES OF H_2O FORMED!

$$n = \frac{PV}{RT} = \frac{(0.521\text{ atm})(3.00\text{ L})}{(0.0821)(673\text{ K})} = 0.02829 \text{ moles } H_2O$$

$$x\text{ g }(NH_4)_2CO_3 \text{ reacts} = \frac{0.02829 \text{ mol } H_2O}{} \cdot \frac{1\text{ mol }(NH_4)_2CO_3}{1\text{ mol } H_2O} \cdot \frac{96.0\text{ g}}{1\text{ mol}}$$

$= 2.72\text{ g }(NH_4)_2CO_3$ reacts

$40.0\text{ g} - 2.72\text{ g} = 37.3\text{ g left!}$

f) What is the minimum amount of grams of solid $(NH_4)_2CO_3$ that is necessary to be placed in the flask in order for the system to come to equilibrium?

Since you must have some solid $(NH_4)_2CO_3$ left, the minimum grams needed is just slightly greater than 2.72 grams!