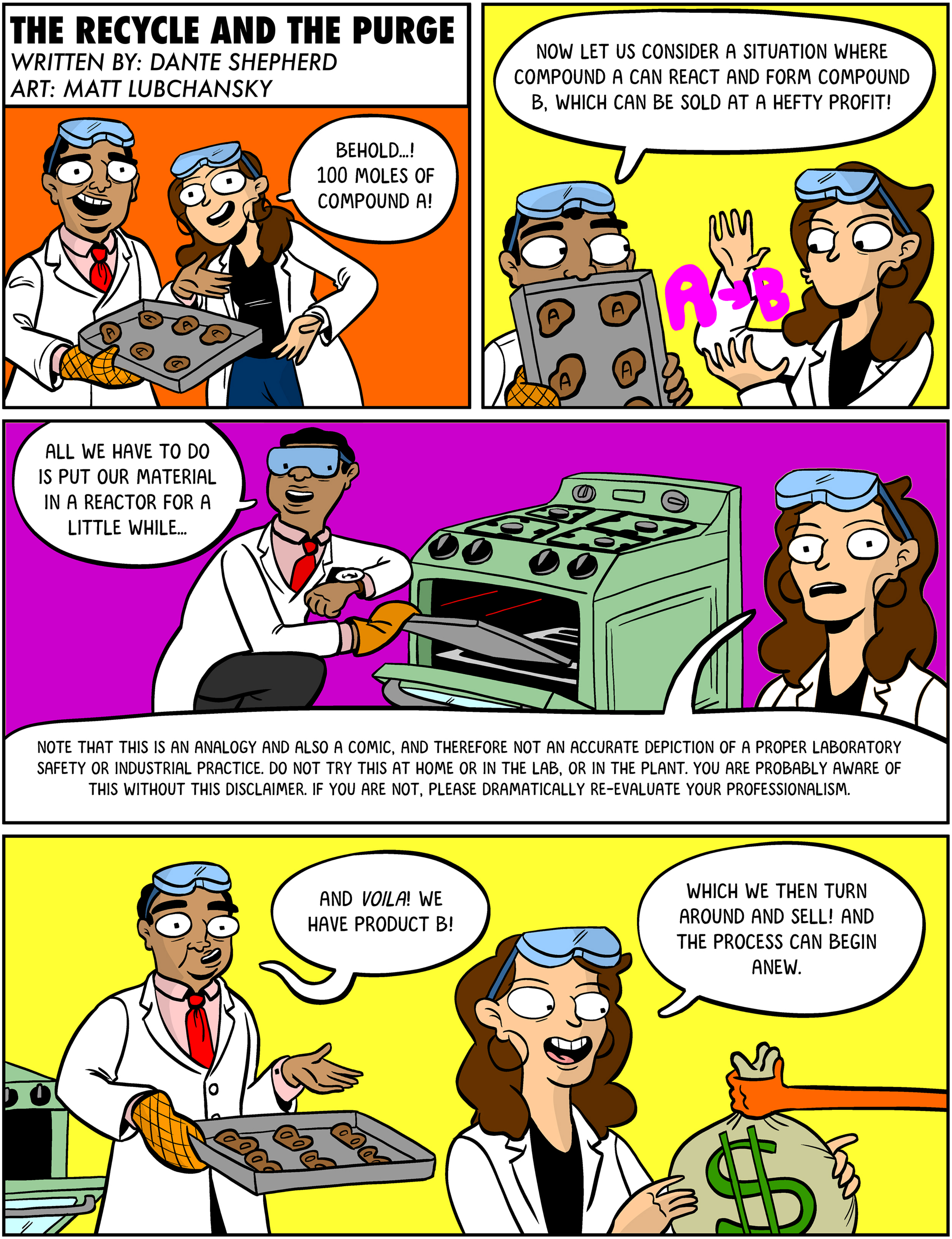
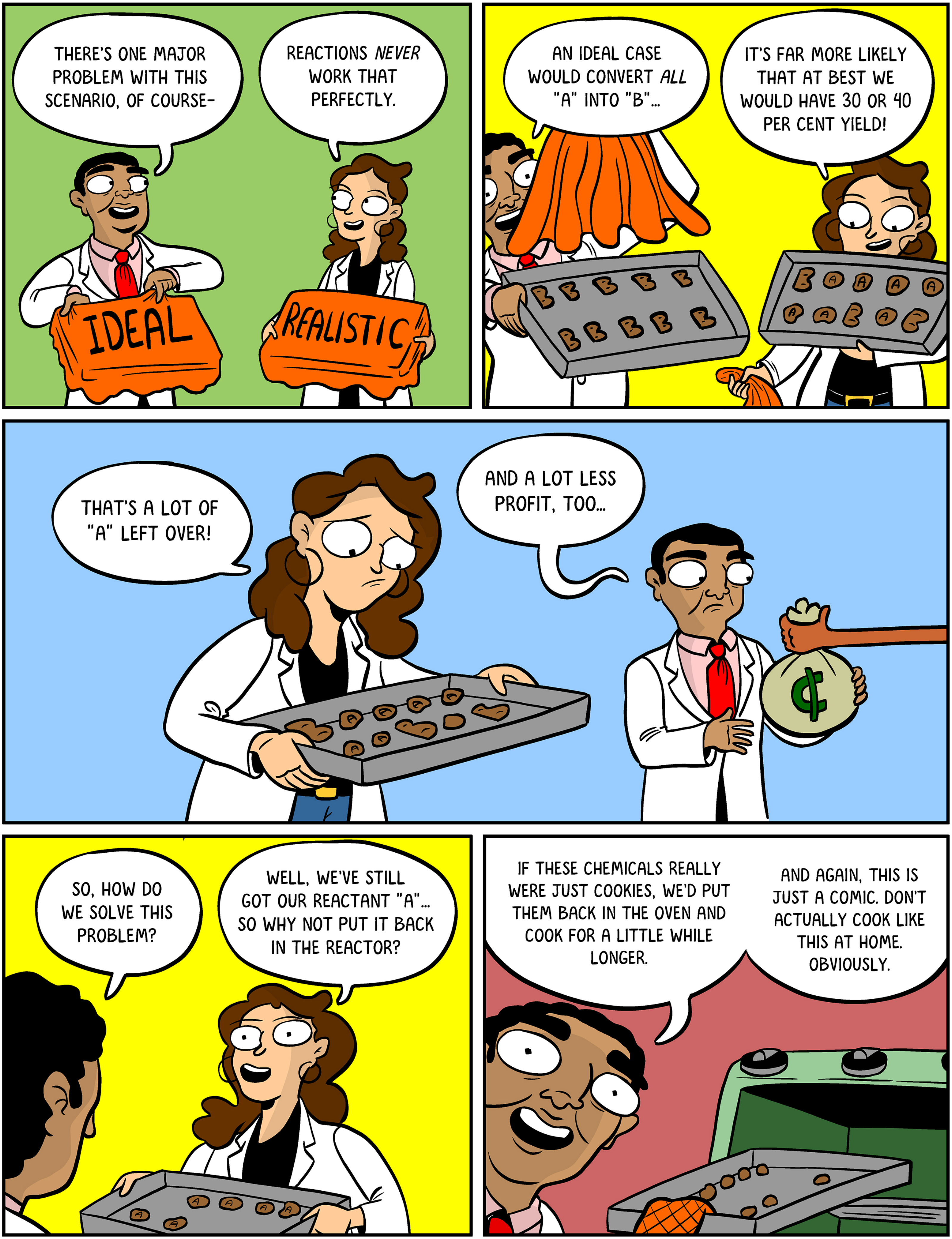
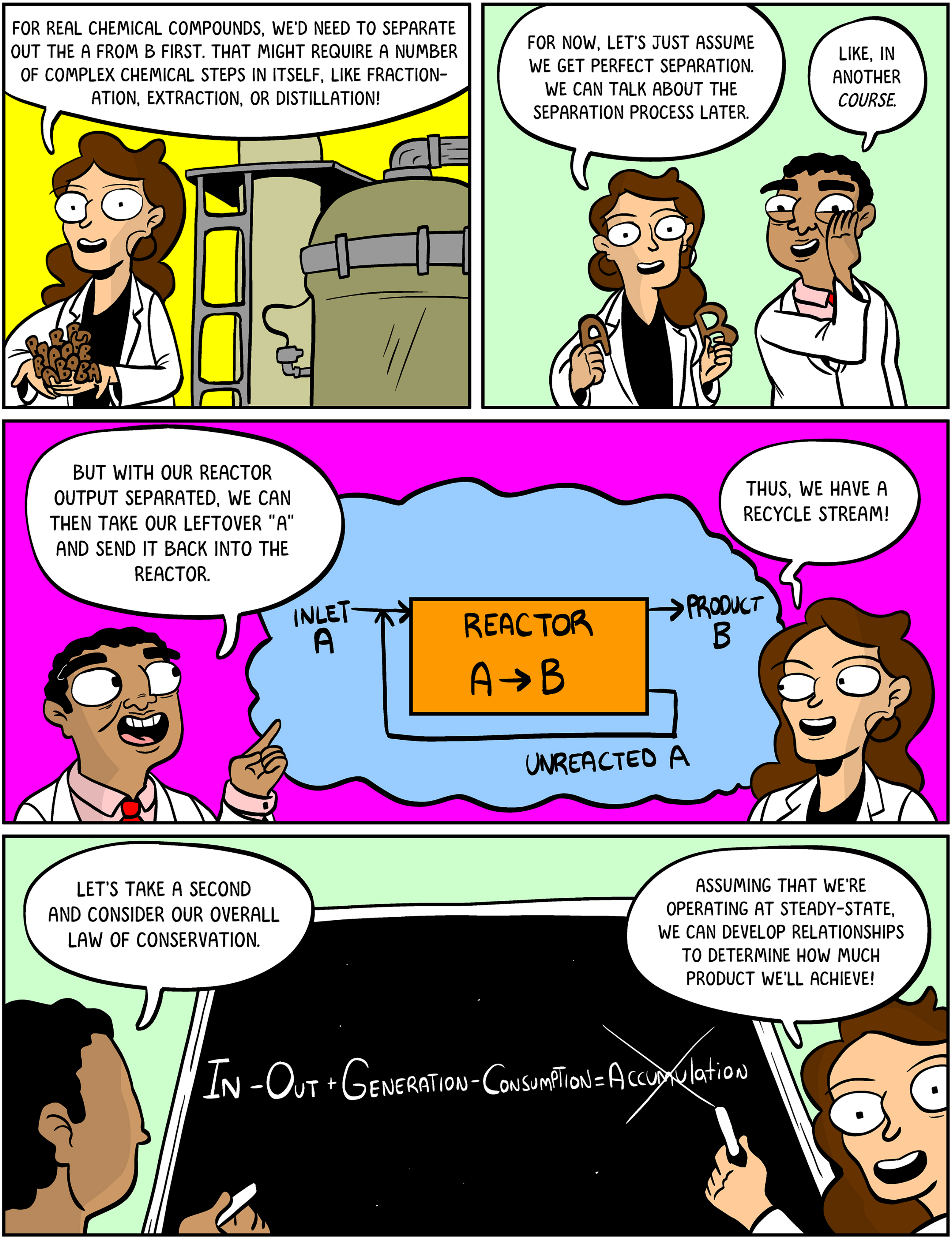
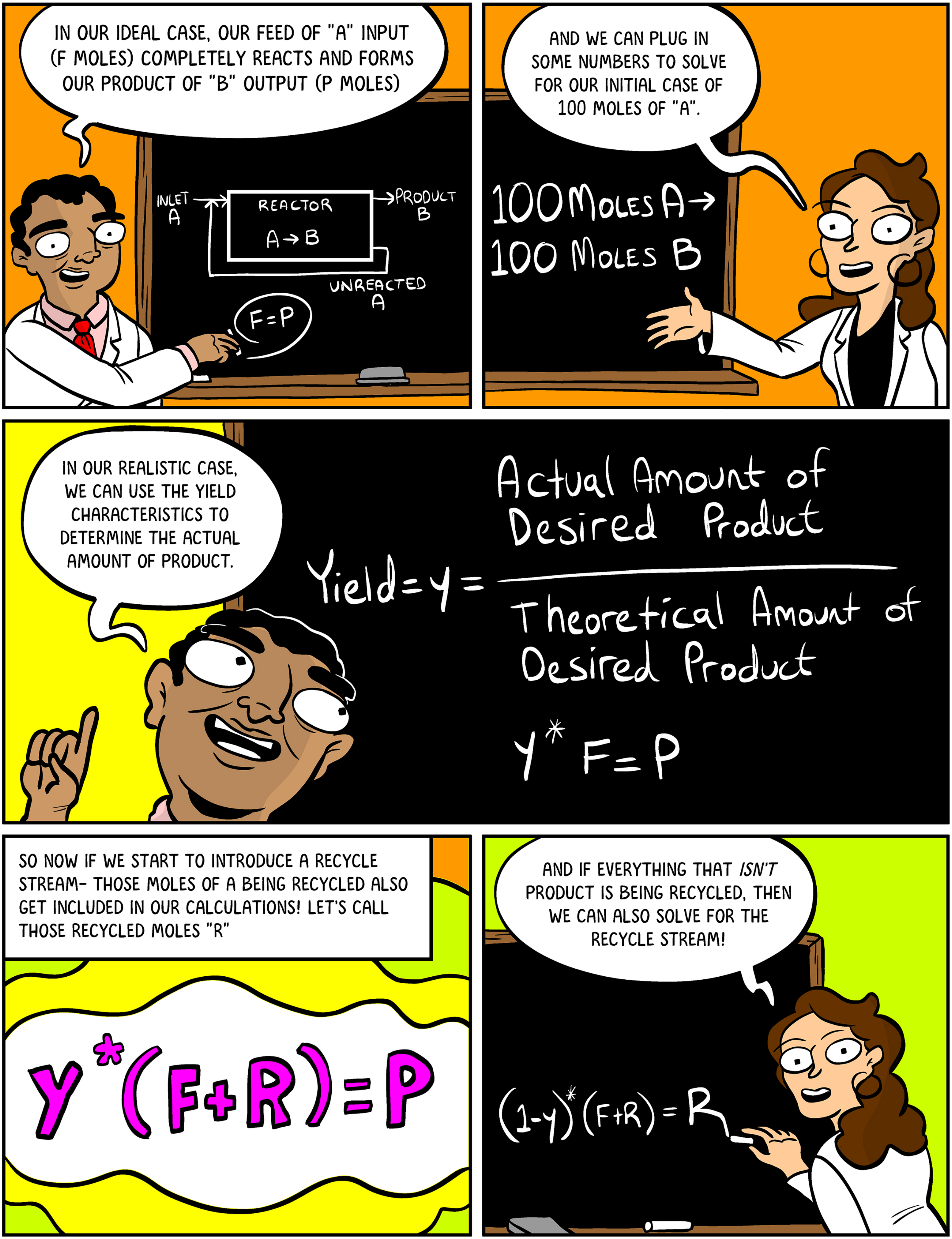

THE RECYCLE AND THE PURGE
WRITTEN BY: DANTE SHEPHERD
ART: MATT LUBCHANSKY
BEHOLD...! 100 MOLES OF COMPOUND A!
NOW LET US CONSIDER A SITUATION WHERE COMPOUND A CAN REACT AND FORM COMPOUND B, WHICH CAN BE SOLD AT A HEFTY PROFIT!
A→B
ALL WE HAVE TO DO IS PUT OUR MATERIAL IN A REACTOR FOR A LITTLE WHILE...
NOTE THAT THIS IS AN ANALOGY AND ALSO A COMIC, AND THEREFORE NOT AN ACCURATE DEPICTION OF A PROPER LABORATORY SAFETY OR INDUSTRIAL PRACTICE. DO NOT TRY THIS AT HOME OR IN THE LAB, OR IN THE PLANT. YOU ARE PROBABLY AWARE OF THIS WITHOUT THIS DISCLAIMER. IF YOU ARE NOT, PLEASE DRAMATICALLY RE-EVALUATE YOUR PROFESSIONALISM.
AND *VOILA*! WE HAVE PRODUCT B!
WHICH WE THEN TURN AROUND AND SELL! AND THE PROCESS CAN BEGIN ANEW.

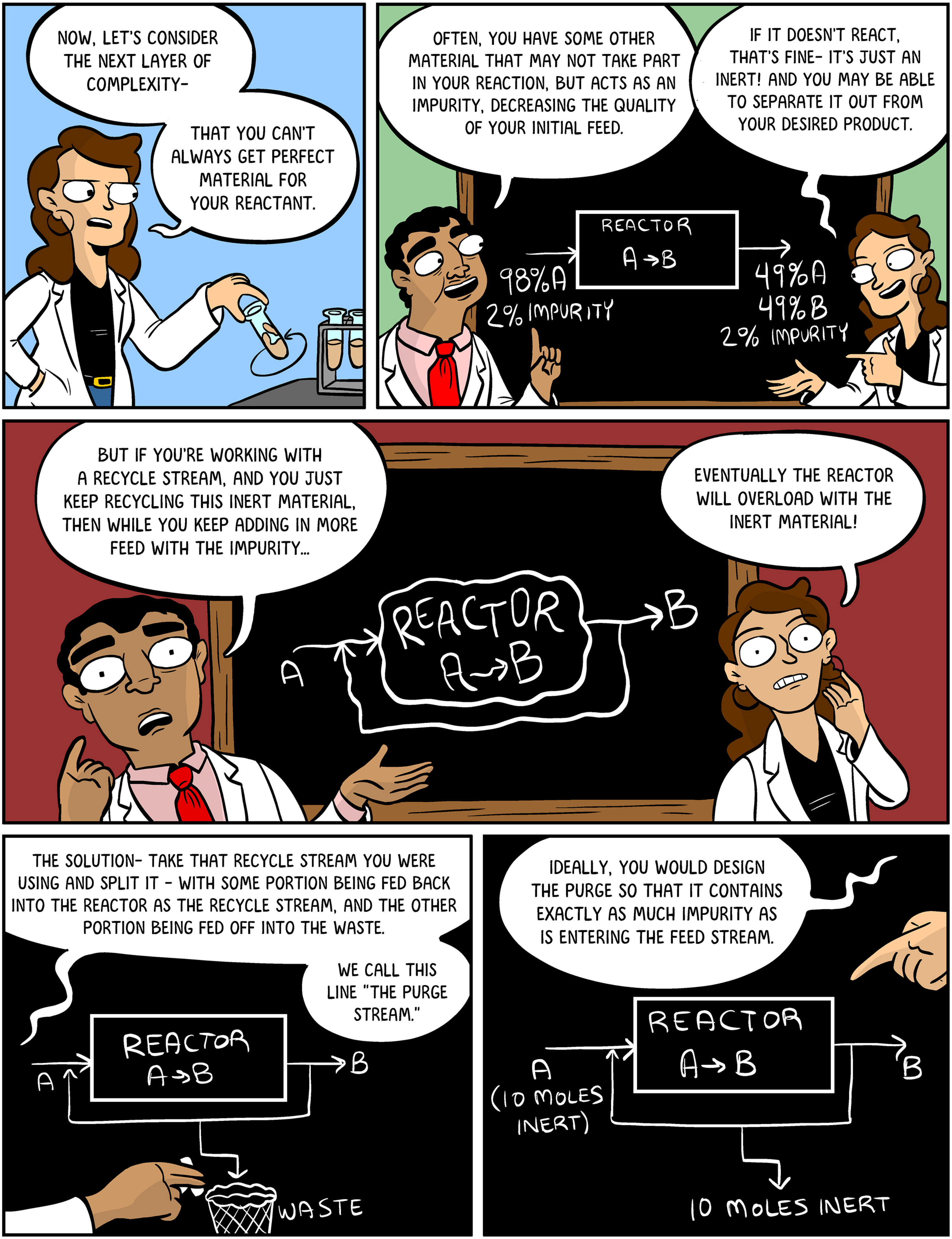


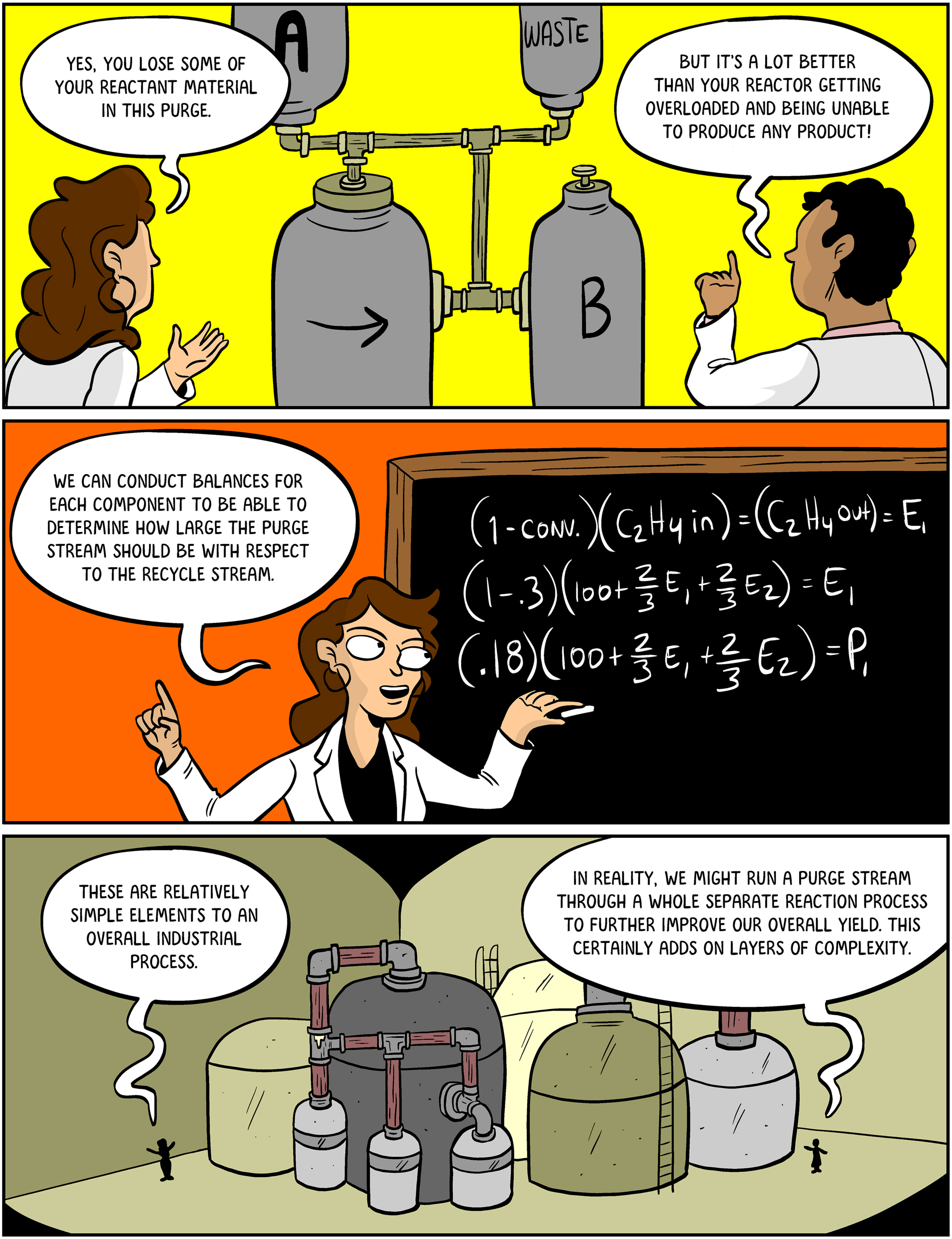
THERE'S ONE MAJOR PROBLEM WITH THIS SCENARIO, OF COURSE-
REACTIONS *NEVER* WORK THAT PERFECTLY.
IDEAL
REALISTIC
AN IDEAL CASE WOULD CONVERT *ALL* "A" INTO "B"...
IT'S FAR MORE LIKELY THAT AT BEST WE WOULD HAVE 30 OR 40 PER CENT YIELD!
THAT'S A LOT OF "A" LEFT OVER!
AND A LOT LESS PROFIT, TOO...
SO, HOW DO WE SOLVE THIS PROBLEM?
WELL, WE'VE STILL GOT OUR REACTANT "A"... SO WHY NOT PUT IT BACK IN THE REACTOR?
IF THESE CHEMICALS REALLY WERE JUST COOKIES, WE'D PUT THEM BACK IN THE OVEN AND COOK FOR A LITTLE WHILE LONGER.
AND AGAIN, THIS IS JUST A COMIC. DON'T ACTUALLY COOK LIKE THIS AT HOME. OBVIOUSLY.

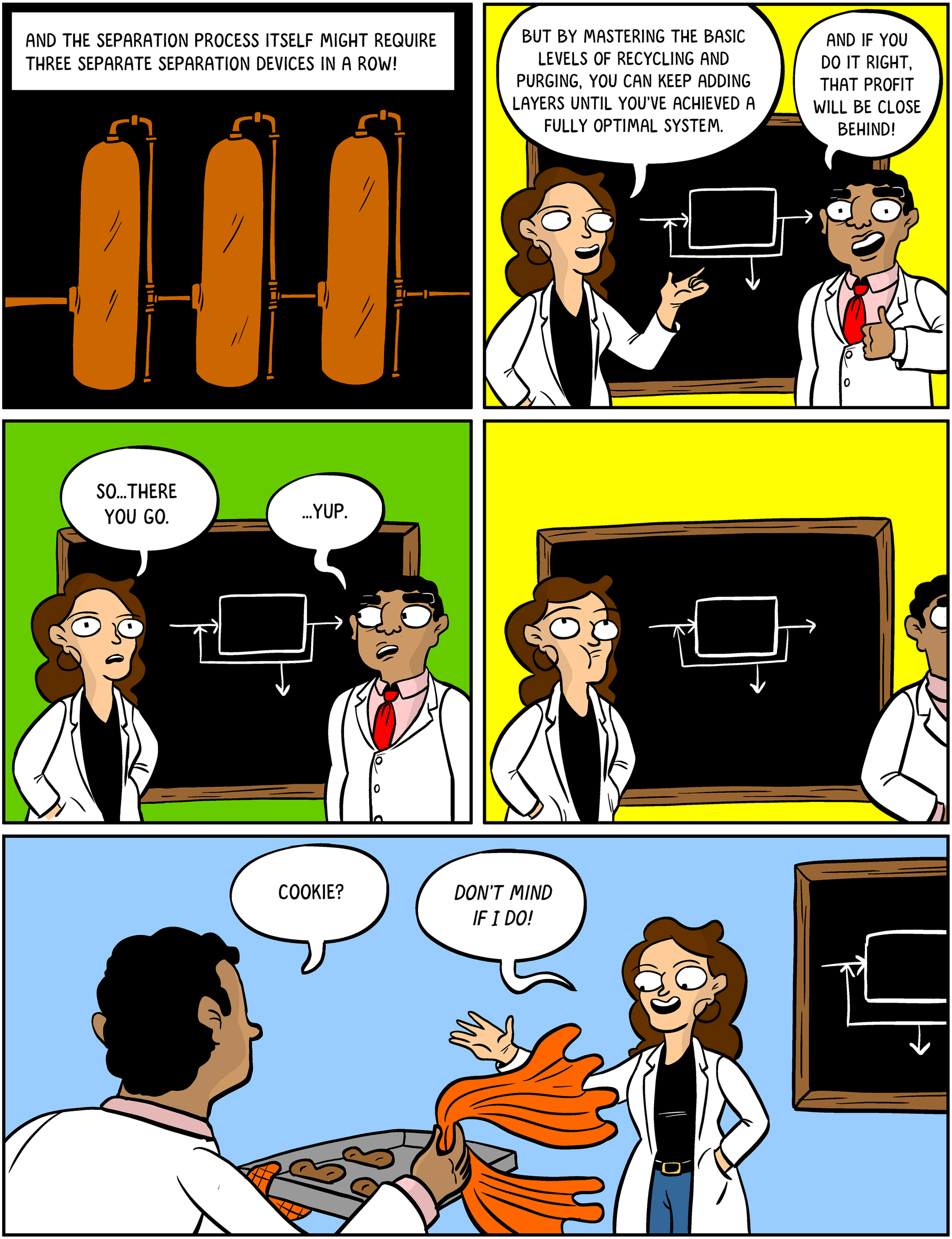

FOR REAL CHEMICAL COMPOUNDS, WE'D NEED TO SEPARATE OUT THE A FROM B FIRST. THAT MIGHT REQUIRE A NUMBER OF COMPLEX CHEMICAL STEPS IN ITSELF, LIKE FRACTION-ATION, EXTRACTION, OR DISTILLATION!
FOR NOW, LET'S JUST ASSUME WE GET PERFECT SEPARATION. WE CAN TALK ABOUT THE SEPARATION PROCESS LATER.
LIKE, IN ANOTHER *COURSE*.
A
B
BUT WITH OUR REACTOR OUTPUT SEPARATED, WE CAN THEN TAKE OUR LEFTOVER "A" AND SEND IT BACK INTO THE REACTOR.
THUS, WE HAVE A RECYCLE STREAM!
INLET A
REACTOR
A → B
PRODUCT B
UNREACTED A
LET'S TAKE A SECOND AND CONSIDER OUR OVERALL LAW OF CONSERVATION.
ASSUMING THAT WE'RE OPERATING AT STEADY-STATE, WE CAN DEVELOP RELATIONSHIPS TO DETERMINE HOW MUCH PRODUCT WE'LL ACHIEVE!
In - Out + Generation - Consumption = Accumulation


IN OUR IDEAL CASE, OUR FEED OF "A" INPUT (F MOLES) COMPLETELY REACTS AND FORMS OUR PRODUCT OF "B" OUTPUT (P MOLES)
INLET A
REACTOR
A→B
PRODUCT B
UNREACTED A
F=P
AND WE CAN PLUG IN SOME NUMBERS TO SOLVE FOR OUR INITIAL CASE OF 100 MOLES OF "A".
100 Moles A→
100 Moles B
IN OUR REALISTIC CASE, WE CAN USE THE YIELD CHARACTERISTICS TO DETERMINE THE ACTUAL AMOUNT OF PRODUCT.
Yield=y= Actual Amount of Desired Product / Theoretical Amount of Desired Product
y* F=P
SO NOW IF WE START TO INTRODUCE A RECYCLE STREAM- THOSE MOLES OF A BEING RECYCLED ALSO GET INCLUDED IN OUR CALCULATIONS! LET'S CALL THOSE RECYCLED MOLES "R"
y*(F+R)=P
AND IF EVERYTHING THAT *ISN'T* PRODUCT IS BEING RECYCLED, THEN WE CAN ALSO SOLVE FOR THE RECYCLE STREAM!
(1-y)*(F+R)=R


YOU SHOULD NOTE THAT THESE GENERAL EQUATIONS WORK IN A NUMBER OF CASES - BUT IF WE HAVE MORE COMPLEX REACTIONS, OR IF WE HAVE SIDE-REACTIONS, WE'D NEED TO MAKE SURE TO ACCOUNT FOR THE COMPLEXITY AND STOICHIOMETRY.
$C_2H_6 \rightarrow C_2H_4 + H_2$
$C_2H_6 + H_2 \rightarrow 2CH_4$
$C_2H_4 + \frac{1}{2}O_2 \rightarrow C_2H_4O$
$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$
NOW LET'S PLUG IN SOME NUMBERS. IF WE'VE GOT 100 MOLES OF FEED AND 30 PER CENT YIELD (SO THAT Y=0.3), THEN IF WE HAD NO RECYCLE STREAM:
0.3*100=P= 30 MOLES OF "B" OUTPUT
AND IF WE *DO* HAVE A RECYCLE STREAM:
(1-.3)*(100+R)=R
70+.7*R=R
70=.3xR
R=233 MOLES OF "A" RECYCLED
SO WE HAVE A LOT MORE B BEING OUTPUT!
AND THUS WE CAN MAINTAIN A GOOD PROFIT!
THAT'S A LOT OF A BEING RECYCLED- MORE THAN TWICE THE NUMBER OF MOLES WE WERE FEEDING IN.
A
B
UNREACTED A
Y*F=P
BUT THAT'S ASSUMING A CONTINUOUS PROCESS- ONCE THE PROCESS IS RUNNING AT STEADY-STATE, MORE THAN A FEW OF THE INITIAL "100 MOLES OF A" HAVE BEEN INPUT. SO THAT MUCH BEING RECYCLED ISN'T THAT UNREALISTIC!


NOW, LET'S CONSIDER THE NEXT LAYER OF COMPLEXITY-
THAT YOU CAN'T ALWAYS GET PERFECT MATERIAL FOR YOUR REACTANT.
OFTEN, YOU HAVE SOME OTHER MATERIAL THAT MAY NOT TAKE PART IN YOUR REACTION, BUT ACTS AS AN IMPURITY, DECREASING THE QUALITY OF YOUR INITIAL FEED.
IF IT DOESN'T REACT, THAT'S FINE- IT'S JUST AN INERT! AND YOU MAY BE ABLE TO SEPARATE IT OUT FROM YOUR DESIRED PRODUCT.
REACTOR
A→B
98%A
2% IMPURITY
49%A
49%B
2% IMPURITY
BUT IF YOU'RE WORKING WITH A RECYCLE STREAM, AND YOU JUST KEEP RECYCLING THIS INERT MATERIAL, THEN WHILE YOU KEEP ADDING IN MORE FEED WITH THE IMPURITY...
EVENTUALLY THE REACTOR WILL OVERLOAD WITH THE INERT MATERIAL!
A
REACTOR
A→B
B
THE SOLUTION- TAKE THAT RECYCLE STREAM YOU WERE USING AND SPLIT IT - WITH SOME PORTION BEING FED BACK INTO THE REACTOR AS THE RECYCLE STREAM, AND THE OTHER PORTION BEING FED OFF INTO THE WASTE.
WE CALL THIS LINE "THE PURGE STREAM."
A
REACTOR
A→B
B
WASTE
IDEALLY, YOU WOULD DESIGN THE PURGE SO THAT IT CONTAINS EXACTLY AS MUCH IMPURITY AS IS ENTERING THE FEED STREAM.
A
(10 MOLES INERT)
REACTOR
A→B
B
10 MOLES INERT


A
WASTE
YES, YOU LOSE SOME OF YOUR REACTANT MATERIAL IN THIS PURGE.
BUT IT'S A LOT BETTER THAN YOUR REACTOR GETTING OVERLOADED AND BEING UNABLE TO PRODUCE ANY PRODUCT!
B
WE CAN CONDUCT BALANCES FOR EACH COMPONENT TO BE ABLE TO DETERMINE HOW LARGE THE PURGE STREAM SHOULD BE WITH RESPECT TO THE RECYCLE STREAM.
$(1-\text{CONV.})(C_2H_4\ \text{in}) = (C_2H_4\ \text{out}) = E_1$
$(1-.3)(100+\frac{2}{3}E_1+\frac{2}{3}E_2) = E_1$
$(.18)(100+\frac{2}{3}E_1+\frac{2}{3}E_2) = P_1$
THESE ARE RELATIVELY SIMPLE ELEMENTS TO AN OVERALL INDUSTRIAL PROCESS.
IN REALITY, WE MIGHT RUN A PURGE STREAM THROUGH A WHOLE SEPARATE REACTION PROCESS TO FURTHER IMPROVE OUR OVERALL YIELD. THIS CERTAINLY ADDS ON LAYERS OF COMPLEXITY.


AND THE SEPARATION PROCESS ITSELF MIGHT REQUIRE THREE SEPARATE SEPARATION DEVICES IN A ROW!
BUT BY MASTERING THE BASIC LEVELS OF RECYCLING AND PURGING, YOU CAN KEEP ADDING LAYERS UNTIL YOU'VE ACHIEVED A FULLY OPTIMAL SYSTEM.
AND IF YOU DO IT RIGHT, THAT PROFIT WILL BE CLOSE BEHIND!
SO...THERE YOU GO.
...YUP.
COOKIE?
DON'T MIND IF I DO!