Carbon Capture, Utilization, and Storage
(이산화탄소 포집, 활용 및 저장) (38535)

- 2023 Final Examination -

Student ID: **Name:**

Notice

- Fill your name below:

  "I, _____, swear I solve all problems by myself in this final examination.

  I will take any disadvantages if any dishonesty such as cheating is acted on my solution."

  5 points will be deducted from your total score if you do not fill in your name above.

- **You MUST solve each problem by hand.**
- Submission Deadline: 12:30~13:45 PM, June 12, 2023

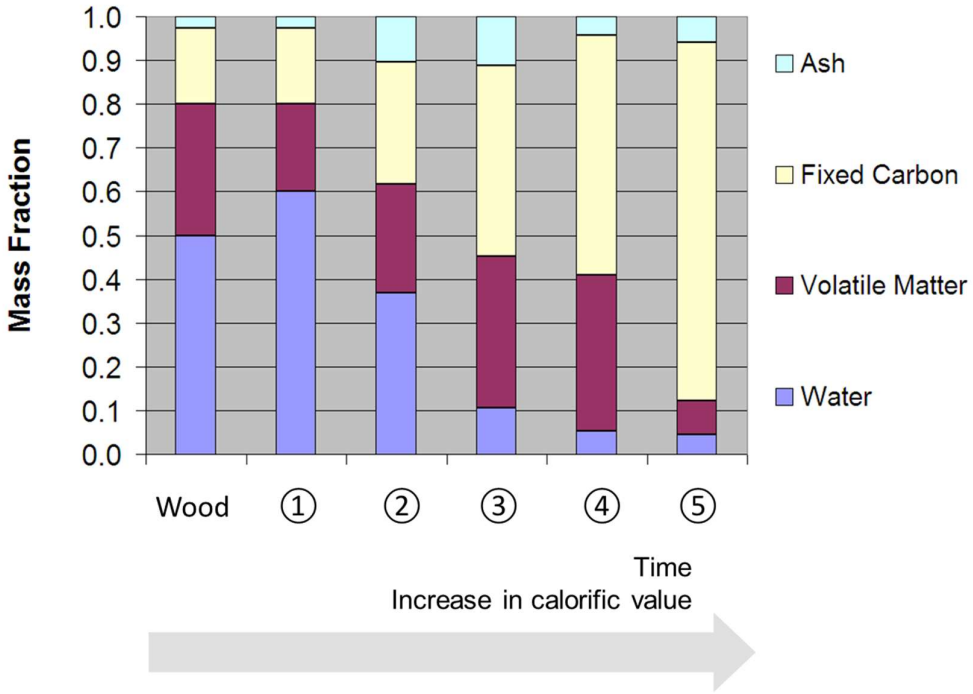
Problem 1.

Provide the full name of each acronym [6 pts.]:

1-1. CCUS [1 pt.]
1-2. IEA [1 pt.]
1-3. DAC [1 pt.]
1-4. NPV [1 pt.]
1-5. CAPEX [1 pt.]
1-6. OPEX [1 pt.]

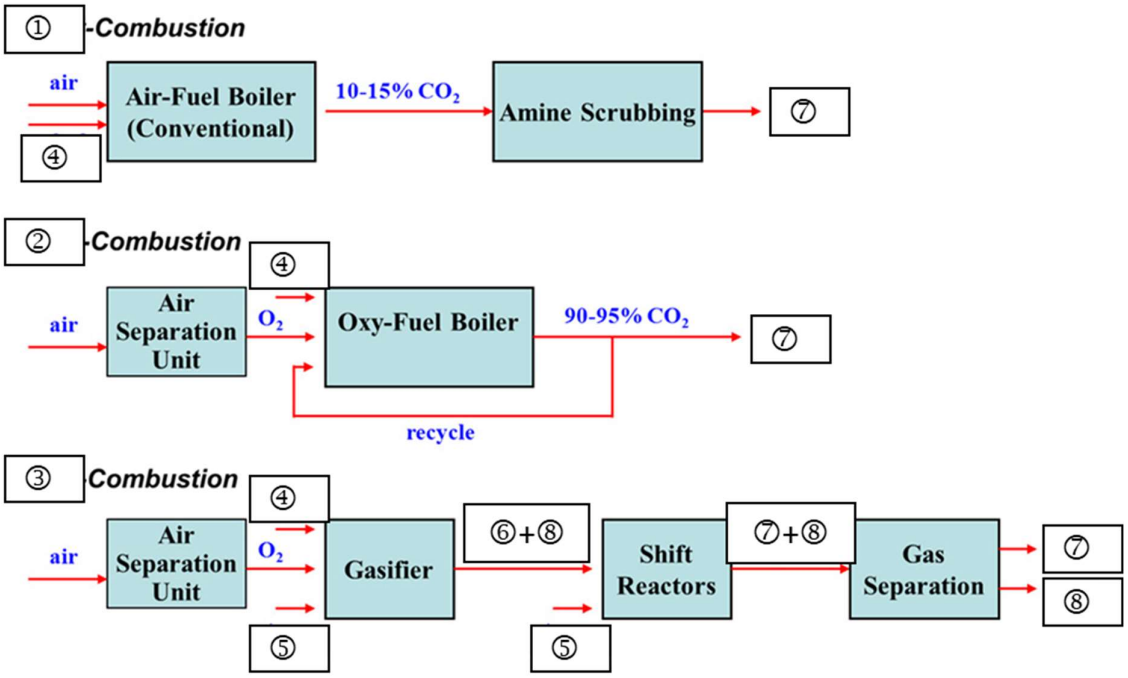
Problem 2.

Below figure shows a typical coal composition. Fill in the blanks from ① to ⑤. [5 pts.].



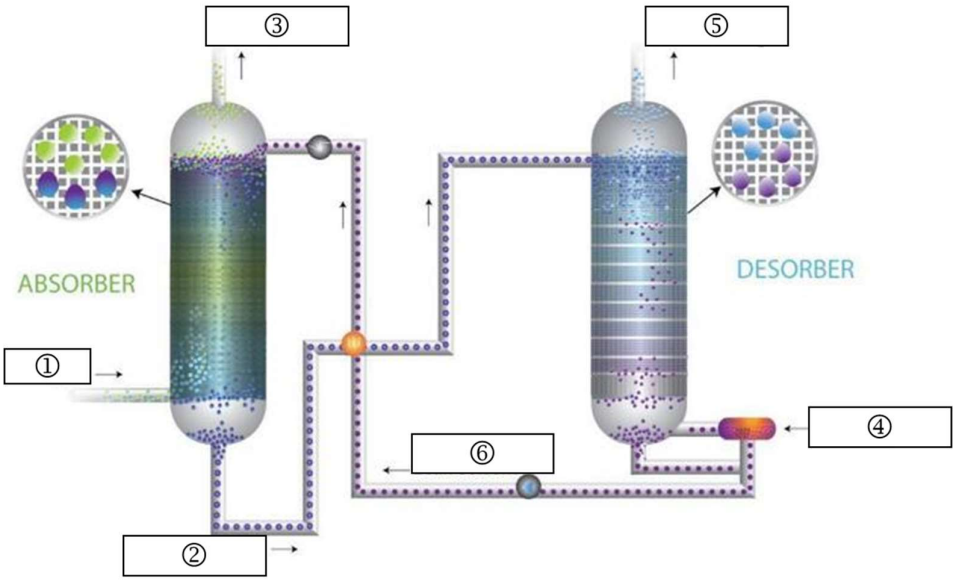
Problem 3.

Fill in the blanks from ① to ⑧. [8 pts.].



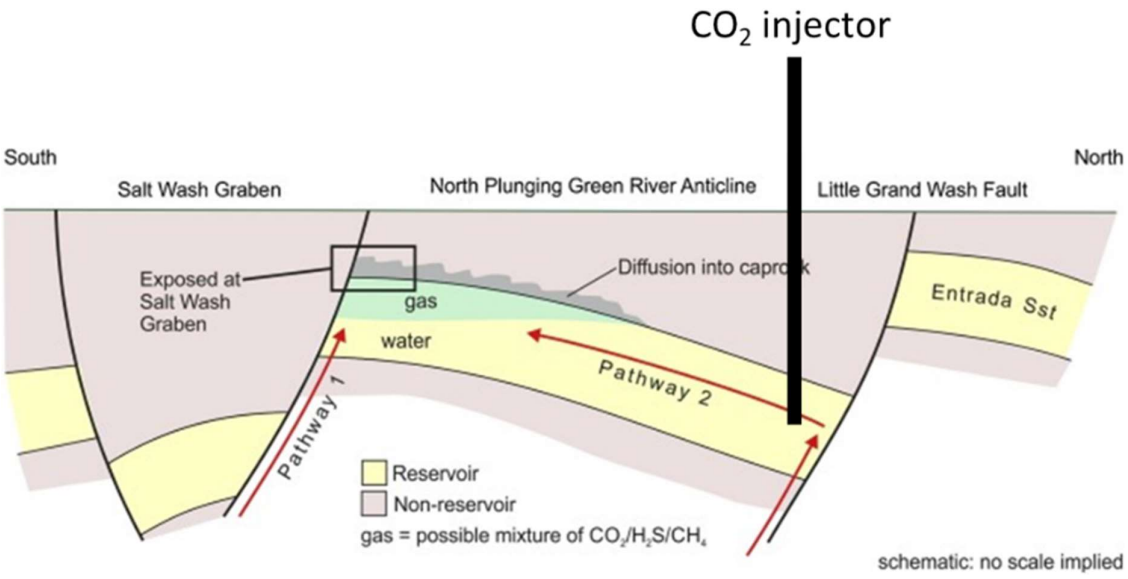
Problem 4.

Fill in the blanks from ① to ⑥ for solvent absorption (i.e., liquid stripping). [6 pts.].



Problem 5.

Field operators plan to inject and store CO_2 permanently in a geological structure with rollover anticline and thrust-faults as follows:



5-1. Draw a fault-seal risk web and seal probability condition. [10 pts.]

5-2. Calculate an overall trap potential probability (P_{trap}) of this storage site to the third decimal place (소수 셋째자리까지 계산하시오). The operators provide the following geological conditions in cooperation with geologists, geophysicists, and petroleum engineers:

- Caprock capacity = 0.95
- Caprock geometry = 0.85
- Caprock integrity = 0.80
- Juxtaposition property = 0.85
- Fault zone property = 0.80
- Post-injection reactivation = 0.1

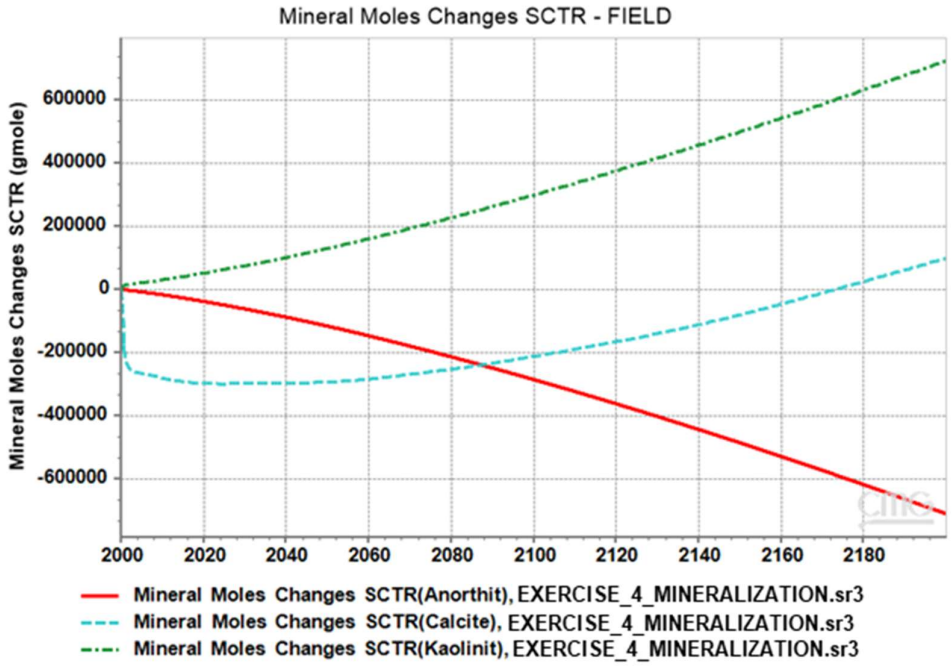
Note that every geological condition above is a probability value ranging between 0 and 1. [10 pts.]

5-3. Based on your engineering knowledge on the overall trap potential, judge if this site is a good candidate for a geological carbon storage project. [5 pts.]

Problem 6.

For a pilot CCS project, assume that a CCS operator injects CO_2 for 1 year, stops the injection, and monitors the migration of CO_2 plume for 199 years at a saline aquifer. This aquifer consists of three facies (i.e., rock types): Anorthite, Calcite, and Kaolinite. The graph below shows a change of mineral mole fractions caused by the mineral trapping mechanism.

Interpret the graph with chemical formulae related to the mineral trapping mechanism (e.g., acid-base chemical reaction and aqueous phase reactions) [20 pts].



Problem 7.

Explain the conversion of the Donghae-1 gas reservoir to a geological carbon storage site with 10 sentences. You will get 1 point for each sentence if its explanation is correct. [10 pts.]

Problem 8.

Solve the problem under the following conditions.

- An offshore natural gas reservoir in Malaysia is under development in order to produce natural gas of 40 Bcf (Bcf = billion cubic feet) annually for 20 years.
- During 20-year natural gas production, annual CO_2 produced from the gas reservoir is 400,000 tonnes of CO_2. If you do not conduct CCS, all the produced CO_2 will be emitted to the atmosphere.

[Plant w/o CCS]

- For a natural gas processing plant without CCS facilities, the estimated costs are as follows:
- CAPEX to build a natural gas processing plant w/o CCS is $300 million (300 $MM).
- Annual OPEX w/o CCS is $40 million (40 $MM/year).
- Decommissioning cost w/o CCS is $50 million (50 $MM).

[Plant w/ CCS]

- If you additionally install CCS facilities to this natural gas processing plant, the estimated costs are as follows:
- CAPEX to build the plant w/ CCS is 350 $MM = 300 $MM + 50 $MM.
- Annual OPEX w/ CCS is 45 $MM/year = 40 $MM/year + 5 $MM/year.
- Decommissioning cost w/ CCS is 54 $MM = 50 $MM + 4 $MM.

[Field Lift Cycle]

- Total field life cycle is 24 years as follows:
- 2 years for plant construction (split the CAPEX evenly over the first 2 years)
- 20 years for natural gas production
- 2 years for decommissioning (split the decommissioning cost evenly over the last 2 years)
- No CO_2 is produced during plant construction and decommissioning.

[Financial Data]

- All produced gas is sold to the energy market with the natural gas price of 5 $/Mcf (Mcf = thousand cubic feet)
- Discount rate = 10%

8-1. Note that the incremental cost of natural gas production = the net profit of natural gas production w/o CCS - the net profit of natural gas production w/ CCS. How much is the incremental cost of natural gas production ($/Mcf)? [10 pts.]

8-2. How much is the cost of CO_2 avoided ($/tonne)? [10 pts.]

---------- This is the End of the Final Examination ----------