[redacted]

Exam GEO4 – 1437 – Sustainable and unconventional resources
26 May 2014 – 13:30 - 16:30

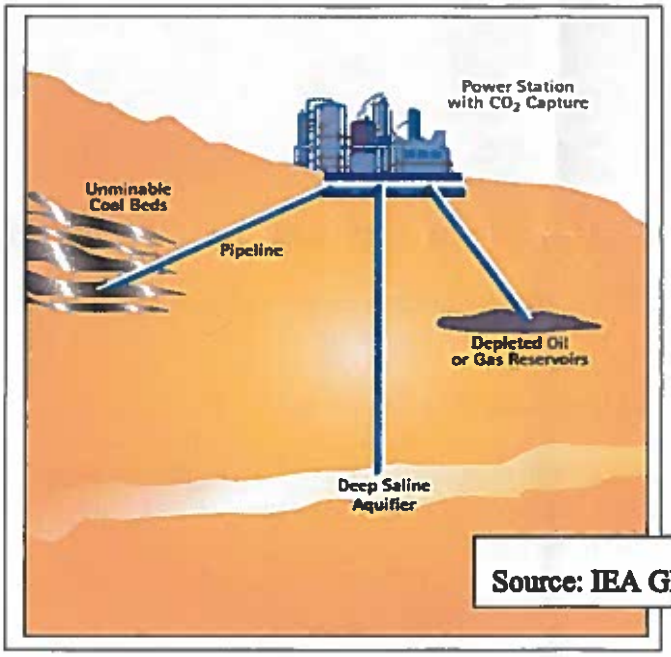
In total 15 questions are asked, grouped in 5 subjects. The weighting of all questions is equal. Write all your responses on separate sheets by keeping in the space allotted. You may draw and explain directly on the Figures, but do not forget to hand in these figures with the response sheets. Please indicate your name on every page.

Subject 1 - Thermal structure of sedimentary basins. *10 minutes, 1 point*

a. Briefly describe and explain three parameters of an EGS production system that will help to increase/maximise electricity production.

Subject 2 - Geological storage resources and carbon dioxide sequestration. *40 minutes, 4 points*

As you know from the course, carbon dioxide capture, coupled with geological storage, forms a key component of almost all IPCC scenarios for reducing emissions to the atmosphere. The main types of geological reservoirs are shown schematically in the figure below. Address the questions posed.



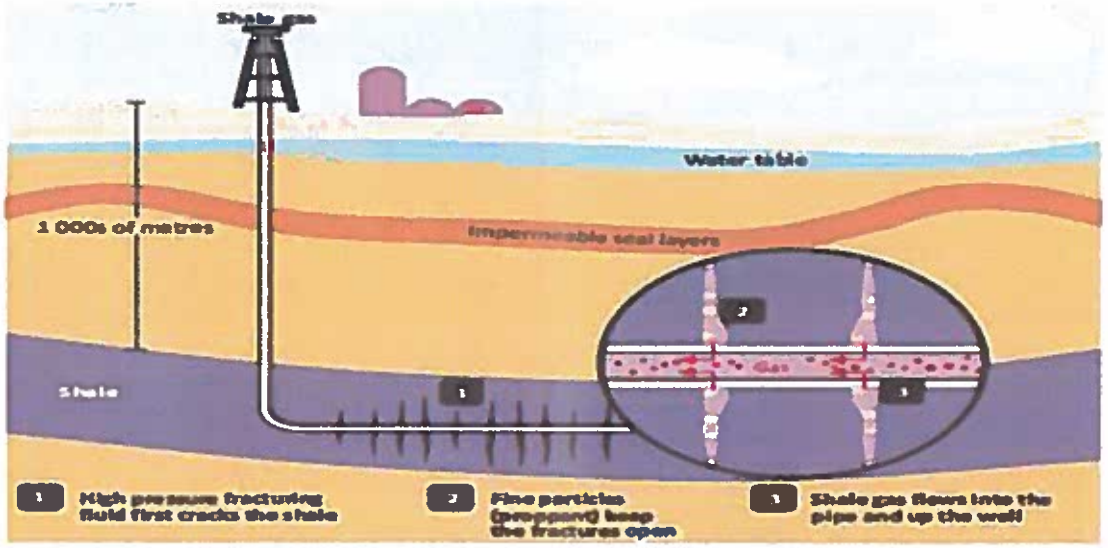
Source: IEA GHG R&D Programme

a. What are the trapping mechanisms associated with each of these types of storage reservoirs and how do they work? Explain your answers in terms of the relevant physical and chemical processes.
b. List the potential advantages of injecting and storing CO2 in un-mineable, methane-rich coal beds? List also the problems that are faced in considering injection and storage in such coal deposits. What might be a way to perhaps overcome these problems?
c. In the situation of the Netherlands, which option in the above diagram is the most promising for CO2 storage and why? Indicate why the other options are less favourable. Address capacity aspects, technical/safety aspects, economic and public opinion aspects.
d. Imagine you have just been awarded a job at the Netherlands National Geosciences Research Centre (TNO). Your first assignment is to evaluate the CO2 storage capacity of a superficially

favourable reservoir located on-land, near the Groningen gas field. You are also tasked with evaluating the likely risks of CO2 injection and long-term storage. Design a brief workflow covering the main issues that would need to be considered. Illustrate your answer with any sketches or equations that might be useful. Define the terms in any equations you use.

Subject 3 - Shale gas exploitation. 20 minutes, 2 points.

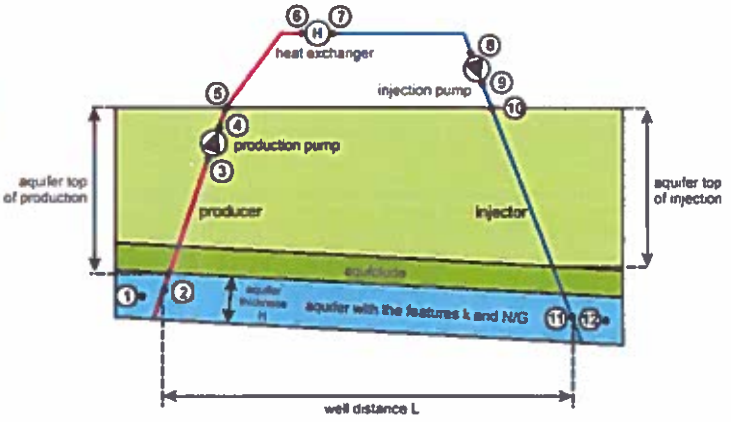
The figure below shows a typical technological deployment for exploitation of shale gas.



a. Describe three (environmental) risks that can occur when drilling and hydraulic fracturing for shale gas.
b. For each risk describe the process occurring, what the possible (negative) consequences are and how they can be avoided.

Subject 4 – Geothermal energy. 40 minutes, 4 points.

Geothermal heat production in the Netherlands from deep aquifers (ca. 2-3 km depth) has grown rapidly over the past 10 years. Heat production deploys doublet systems, marked by a producer and injector well as indicated in the figure located to the right.



a. Currently ca. 10 doublets are operational. What is the geothermal heat mostly used for?

[redacted]

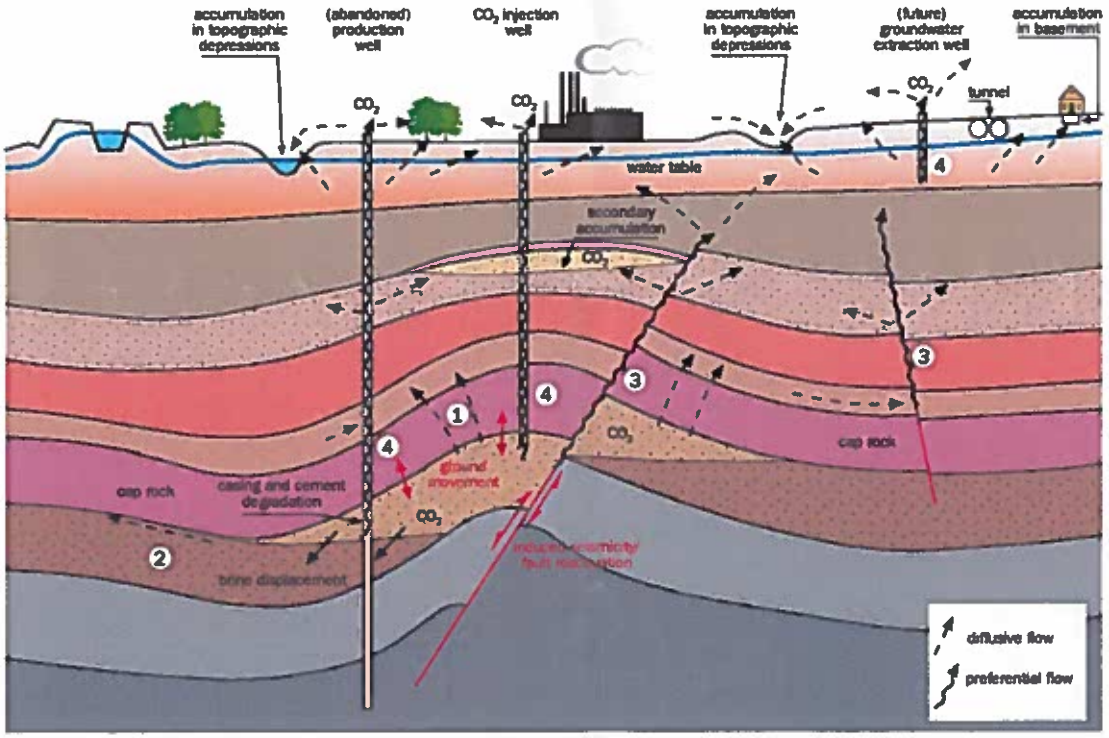
b. In the Netherlands, which (policy) actions concerning management of subsurface data and addressing non-technical barriers have significantly facilitated geothermal development?

c. For an aquifer in the Netherlands, key reservoir parameters and their uncertainties have been assessed according to the table below. Rank the impact of the uncertainty in the parameters in terms of the resulting variation in Levelized Cost of Energy (LCOE). Rank 1 means largest impact, 3 lowest impact on LCOE. Equal ranks may be used. Motivate your choices.

Reservoir parameter	Min	median	Max	LCOE rank(choose from 1-3)
Temperature	67 C	70 C	73 C	3
Permeability	50 mD	100mD	200 mD	1
Thickness	90 m	100 m	110 m	2

d. In the right hand panel, the producer well is located at the shallowest part of the aquifer and the injector at the deepest. Is this the best choice or should it be reversed? Why?

Subject 5 - CO_2 storage. 40 minutes, 4 points.



a. What are potential migration pathways (4) to be managed during risk management of CO2 storage (see Figure above)?

b. What is the most frequently used technique for monitoring CO2 plum (see Figure above) in the subsurface (and geological structure of subsurface)? Describe possible variations of the technique (like different topography or components or modes in which it can be used) and the principles on which it is based (what do you exactly measure and how can you tell where CO2 is)?

c. How can subsidence be used as monitoring tool for CCS?

d. List at least four controlling parameters for induced seismicity.