Kimia Fisika-TKG 1108

Fenomena multifase

Ferian Anggara

Materi dan Jadwal Kuliah

Minggu ke	Tanggal	Topik	Pengampu	Keterangan
1	19-Feb 20-Feb	Pendahuluan: Periodic System and Chrystal Chemistry of Rock Forming Minerals	Nugroho Imam Setiawan	Libur Imlek
2	26-Feb 27-Feb	Properties of Gases	Rahmadi Hidayat	
3	5-Mar 6-Mar			
4	12-Mar 13-Mar	Hukum 1 Termodinamika	Rahmadi Hidayat	
5	19-Mar 20-Mar			
6	26-Mar 27-Mar	Hukum 2 Termodinamika	Rahmadi Hidayat	
7	2-Apr 3-Apr			Libur Paskah
8	23-Apr 24-Apr	Multiphase phenomena	Ferian Anggara	
9	30-Apr 1-May			Hari Buruh
10	7-May 8-May	PVT data	Ferian Anggara	
11	14-May 15-May	Phase Diagram	Nugroho Imam Setiawan	Kenaikan Isa Almasih
12	21-May 22-May			
13	28-May 29-May	Chemical Equilibrium	Nugroho Imam Setiawan	
14	4-Jun 5-Jun			

Ujian Tengah Semester

Outline

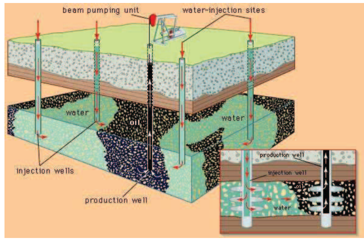
Multiphase phenomena
- Introduction
- Wettability
- Capillary pressure
- Relative permeability

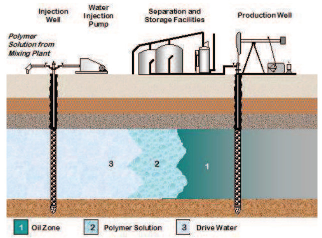
PVT data
- Introduction
- Adsorption/Desorption Test
- Numerical modelling
- Case study: CO_2 injection into reservoir

Multiphase phenomena

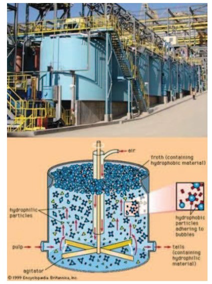
- Introduction
- Wettability
  - Contact angle
  - Capillary pressure
- Case studies
  - Mineral processing (coal separation, mineral separation, etc)
  - Hydrocarbon migration and production (water flooding and enhanced recovery technique)

Enhanced oil recovery

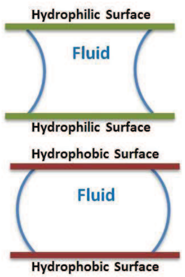




Mineral processing



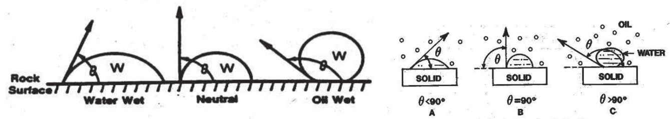
Hydrophobic - Hydrophilic



Wettability

- the preference of a solid to be in contact with one fluid rather than another (Abdullah et al., 2007)
- the ability of a fluid phase to preferentially wet a solid surface in the presence of a second immiscible phase
- wettability is generally classified into three categories:
  1. The reservoir is said to be water wet; that is, water preferentially wets the reservoir rock, when the contact angle (θ)between the rock and water is less than 90°,
  2. neutral wettability case would exist at a contact angle of 90°, and
  3. oil wet occurs at a contact angle greater than 90°.

Wettability



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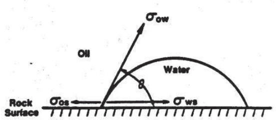
Contact angle



is a measure of the wettability of the rock-fluid system, and is related to the interfacial energies by Young's equation

$$\sigma_{os} - \sigma_{ws} = \sigma_{ow} \cos\theta$$

where:

σ_{os} = interfacial energy between oil and solid, dyne/cm;

σ_{ws} = interfacial energy between water and solid, dyne/cm;

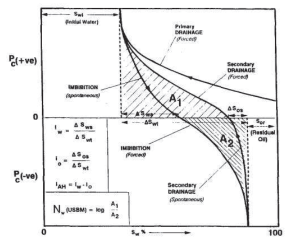
σ_{ow} = interfacial energy, or interfacial tension, between oil and water, dyne/cm;

θ = contact angle at oil-water-solid interface measured through the water phase, deg.

Measurement of contact angle

- Sessile drop method
- Amott wettability test
- United States Bureau of Mines (USBM) wettability test
- Combined USBM-Amott Wettability test

Wettability curve



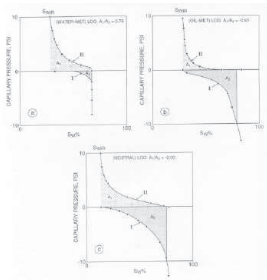
Morrow, 1990

- The drainage is defined as a decrease in water saturation and imbibition as an increase.
- The forced drainage mechanism is characterized by larger pores tending to empty before smaller pores.
- The spontaneous imbibition mechanism is characterized by smaller pores filling before larger pores.
- For systems in which capillary pressure changes sign, as when spontaneous imbibition is followed by forced displacement, a further increase in water saturation occurs by a drainage mechanism. Similarly, a system can exhibit spontaneous imbibition of oil, which by definition is a spontaneous drainage process

Imbibition and drainage

- Imbibition is defined as the intake of a wetting phase into pore spaces of a porous media by capillary forces.
- Drainage is defined as the process of forcing a non-wetting phase into a porous rock, thereby resulting in a decrease in the wetting phase saturation.
- Oil migrates into most reservoirs as the non-wetting phase, decreasing the water saturation, therefore initial charging of the reservoir is a drainage process.
- Imbibition is very important for oil recovery from hydrocarbon reservoirs

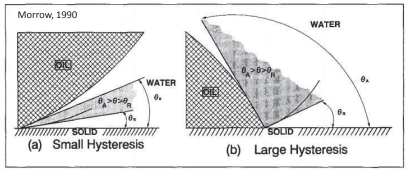
Wettability test



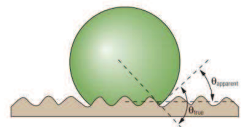
Glover, ...

Measurement of contact angle

1. surface contamination,
2. heterogeneity in chemical composition,
3. surface roughness, and static
4. dynamic interface properties contribute to the complexity of observed wetting phenomena

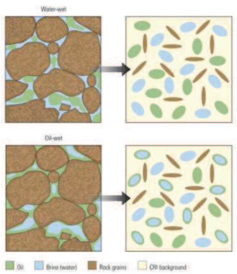


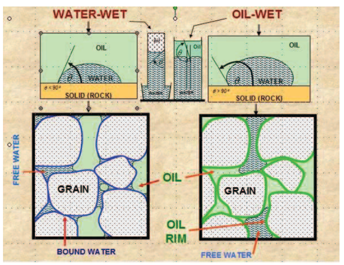
Morrow, 1990



Abdullah et al., 2007

Wettability

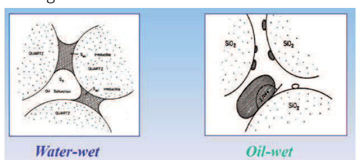




Abdullah et al., 2007

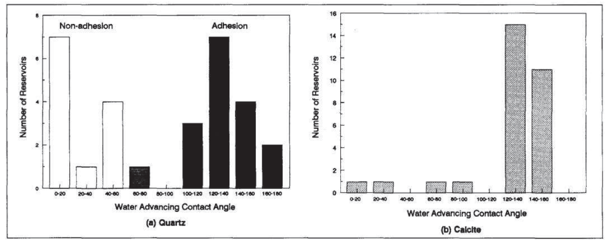
Wettability

- reservoir rocks are complex structures, often comprising a variety of mineral types
- each mineral may have a different wettability, making the wetting character of the composite rock difficult to describe.
- typically, the primary constituents of reservoirs-quartz, carbonate and dolomite-are water-wet prior to oil migration.



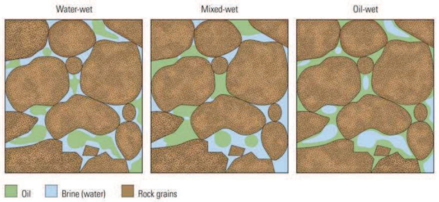
Abdullah et al., 2007

Contact angles for crude-oil/brine systems



Morrow, 1990

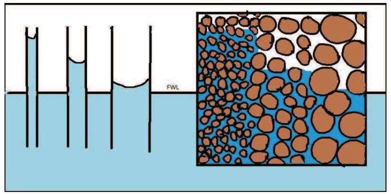
Wetting in pore

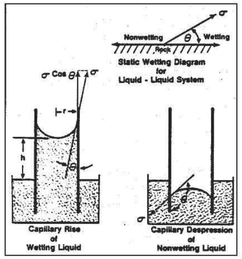


^ Wetting in pores. In a water-wet case (*left*), oil remains in the center of the pores. The reverse condition holds if all surfaces are oil-wet (*right*). In the mixed-wet case, oil has displaced water from some of the surfaces, but is still in the centers of water-wet pores (*middle*). The three conditions shown have similar saturations of water and oil.

Abdullah et al., 2007

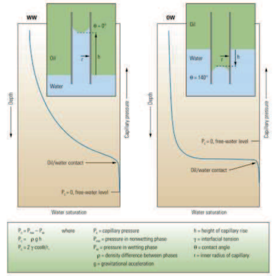
Capillary pressure



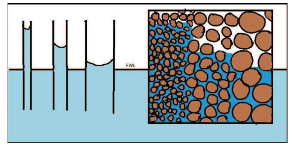


*Pressure difference between the oil and water phase

Transition zone



Abdullah et al., 2007



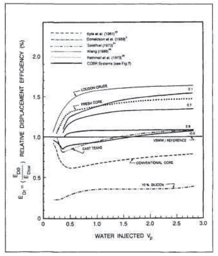
Saturation in reservoir is not static; it's affected by:

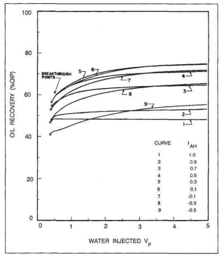
- Multiphase of oil migration
- Development of a gas cap
- Leakage of oil and gas from the reservoir
- Tectonic activity

→ Result in different saturation based in part on the wettability of the surface at the time.

Enhanced recovery

Oil recovery vs. water injected for COBR system





Morrow, 1990

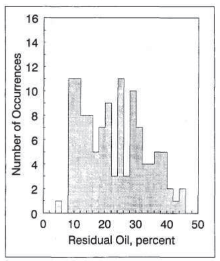
	Water Wet	Neutrally Wet	Oil Wet
Contact angle			
Minimum	0°	60 to 75°	105 to 120°
Maximum	60 to 75°	105 to 120°	180°
USBM wettability index	W near 1	W near 0	W near -1
Amott wettability index			
Displacement by water ratio	Positive	Zero	Zero
Displacement by oil ratio	Zero	Zero	Positive
Amott-Harvey wettability index	0.3 to 1.0	–0.3 to 0.3	–1.0 to –0.3

Closing remark

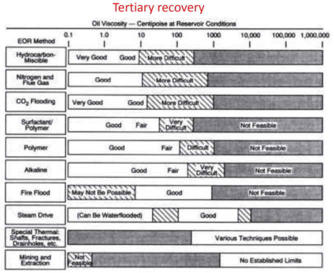
- oil recovery decreasing with decreasing water-wetness.
- This is consistent with the intuitive notion that strong wetting preference of the rock for water and associated strong capillary imbibition forces give the most efficient oil displacement
- an increasing number of examples of improved recovery with shift from strongly water-wet conditions are being reported for weakly water-wet or intermediate wetting condition, particularly for COBR systems
- Lab.scale: Oil recovery is optimum at neutral permeability (Morrow, 1990)

Residual oil saturation

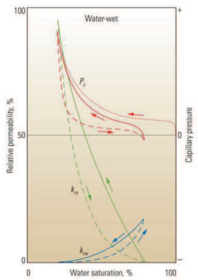
Secondary recovery

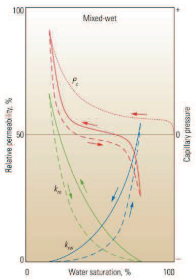


Tertiary recovery



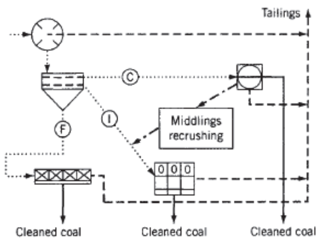
Next meeting – *Relative permeability*

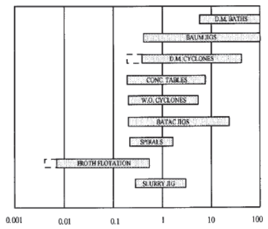




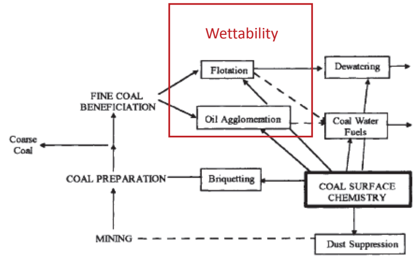
Mineral processing

Coal cleaning technologies



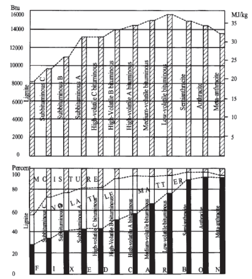


Unit operation based on surface properties



Flotation: a technology by which coal is separated from mineral using the difference in the quality of adhering to air bubble in water

Coal properties vs. rank



Coal flotation

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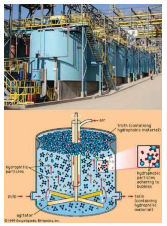
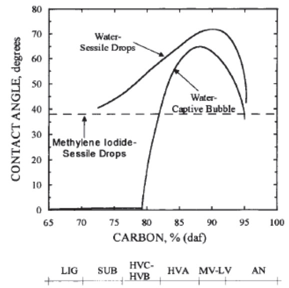
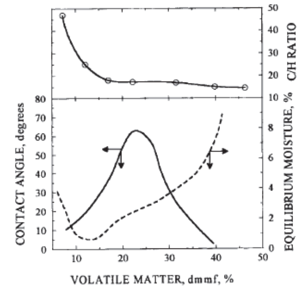


Coal surface wettability

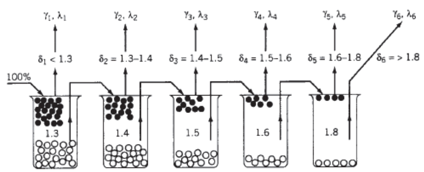
- Relationship between wettability and floatability is not straightforward,
- wettability → contact angle larger than zero ($\theta > 0$) can float
- it is generally assumed that wettability as expressed by contact angle is the most fundamental of flotation-related surface property.
- low-rank coals which are not very hydrophobic float poorly,
- bituminous coals, if not oxidized, are hydrophobic and are easy to float
- coal matrix is assumed to be hydrophobic (to a varying degree), and this hydrophobicity is further modified by the presence of hydrophilic functional groups on the coal surface
- mineral matter impurities which are also hydrophilic.

Contact angle vs. coal rank





Float-sink analysis procedure



End