

1. 請從下列「研究問題集」中任選一題，說明您將如何進行系統性分析 (20%)。

作答規範：

- (1) 方法論述 (6%)：明確指出所選用的分析方法 (如 LCA, MFA, Criticality Assessment 等)，簡述其基本原理 (如質量守恆、生命週期思維) 及為何該方法適用於此問題。
- (2) 研究設計 (7%)：說明執行該研究需蒐集的關鍵數據指標 (至少三項) 以及系統邊界 (System Boundary) 的設定。
- (3) 應用價值 (7%)：說明該分析結果如何輔助決策 (例如：如何改善環境熱點、如何降低供應風險或達成淨零路徑)。

研究問題集 (選一題作答)：

- 面對國際礦物出口管制風險，分析企業應選擇「建置國內閉環回收系統」或「開發多元國外供源」，並評估在不確定情境下的預期收益與最優決策路徑。
- 分析銅金屬在臺南市社會設施 (如電網、建築) 中的淨累積量 (Stock)，並評估未來十年透過「二次資源回收」替代原生礦產進口的供應潛力。
- 比較「純電動車 (BEV)」與「內燃機汽車 (ICEV)」在全生命週期下的溫室氣體排放優劣，並識別其環境影響的「熱點 (Hotspots)」分佈差異。
- 建立一套量化評估架構，從「經濟重要性」與「供給風險」兩大維度，篩選出對臺灣半導體或綠能產業具實質威脅的關鍵礦物清單。
- 評估關鍵原物料 (如鋰或鈷) 在露天開採階段對當地生態系服務 (Ecosystem Services) 的影響及其造成的經濟損失價值。

2. (1) 何謂「關鍵原物料 (Critical Raw Materials)」 (4%)？
- (2) 在評估一項原物料是否具有「關鍵性」時，通常會考量哪兩大核心指標 (6%)？
- (3) 請舉出一種原物料/礦物，說明其在能源轉型中的重要性 (5%)。

3. (1) 「永續物料管理 (Sustainable Material Management, SMM)」與傳統的「廢棄物管理」有何本質上的不同 (6%)?
(2) 請由物料的生命週期角度說明為何 SMM 強調跨階段的整合管理 (4%)。
4. (1) 請解釋何謂「資源脫鉤 (Resource decoupling)」與「衝擊脫鉤 (Impact decoupling)」，並說明兩者的差異 (10%)。
(2) 請解釋何謂「相對脫鉤 (Relative decoupling)」與「絕對脫鉤 (Absolute decoupling)」，並說明兩者的差異 (10%)。
(3) 請從以下三種循環經濟商業模式中擇一，舉出一個具體產業實例，並詳細分析該模式如何藉由「改變物質流動」或「提升能源效率」來達成上述的「脫鉤」目標？(請明確指明達成的是哪一種脫鉤類型) (10%)。
- 產品共享 (Access/Sharing)
 - 產品服務化 (Performance/Product as a Service)
 - 再製造 (Re-make/Remanufacture)
5. 假設臺南市政府計畫在將軍區推動「設置大型太陽能儲能站」專案以加速淨零轉型：
- (1) 請舉出三個不同的利害關係人 (Stakeholders) (6%)；
(2) 分別論述這三個利害關係人在該議題上的「核心利益/動機 (Stakes/Motivations)」為何 (12%)；
(3) 並繪製「利益與影響力矩陣 (Interest vs. Influence/Power Matrix)」 (7%)？

1. A volumetric gas reservoir has the following production history.

Time, t (years)	Reservoir pressure, p (psia)	Z	Cumulative production, G_p (MMMscf)
0.0	1798	0.869	0.00
0.5	1680	1.870	0.96
1.0	1540	0.880	2.12
1.5	1428	0.890	3.21
2.0	1335	0.900	3.92

The following data is also available:

$$\phi = 13\%, S_{wi} = 0.52, A = 1060 \text{ acres}, h = 54 \text{ ft}, T = 164^\circ\text{F}$$

- (1) Calculate the initial gas in place (OGIP) from volumetric method
- (2) Calculate the OGIP from the material balance equation (MBE)
- (3) Compare the estimates of OGIP from volumetric and MBE methods. How much is the percent difference? Which one is the best OGIP estimate for you? Give your explanation.

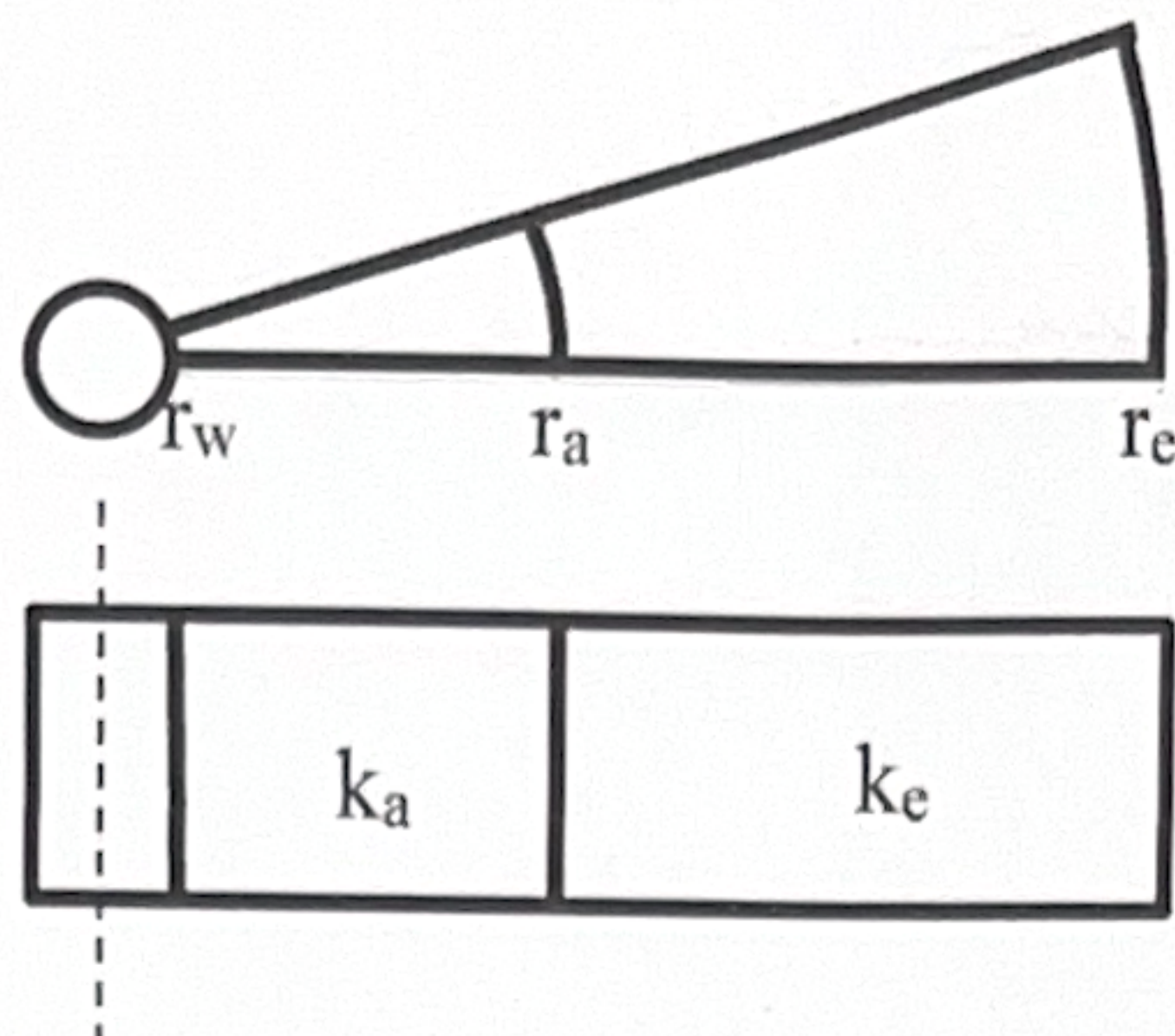
2. Given the following laboratory data:

Cell pressure (psia)	Cell temperature (°F)	Oil volume in cell (cc)	Cumulative gas volume (cc)
2200	200	660	0
1700	200	670	0
1200	200	650	160
700	200	610	720
14.7	60	500	45,000

Assume the measured gas volume is a cumulative quantity, i.e. the gas volume of 45,000 is the maximum cumulative gas volume at standard condition.

- (1) Determine the bubble point pressure (p_b).
- (2) Evaluate R_s , B_o , and B_g at the stated pressures (i.e. at 2200, 1700, 1200, 700 psia). The gas deviation factor at 1200 psia and 700 psia have been evaluated as 0.92 and 0.96, respectively.

3. Consider a radial flow system of constant thickness with a permeability of k_e between the drainage radius r_e and some lesser radius r_a , and an altered permeability k_a between the radius r_a and the wellbore radius r_w . Derive the average permeability (平均滲透率, $\bar{k}$) in this formation system.



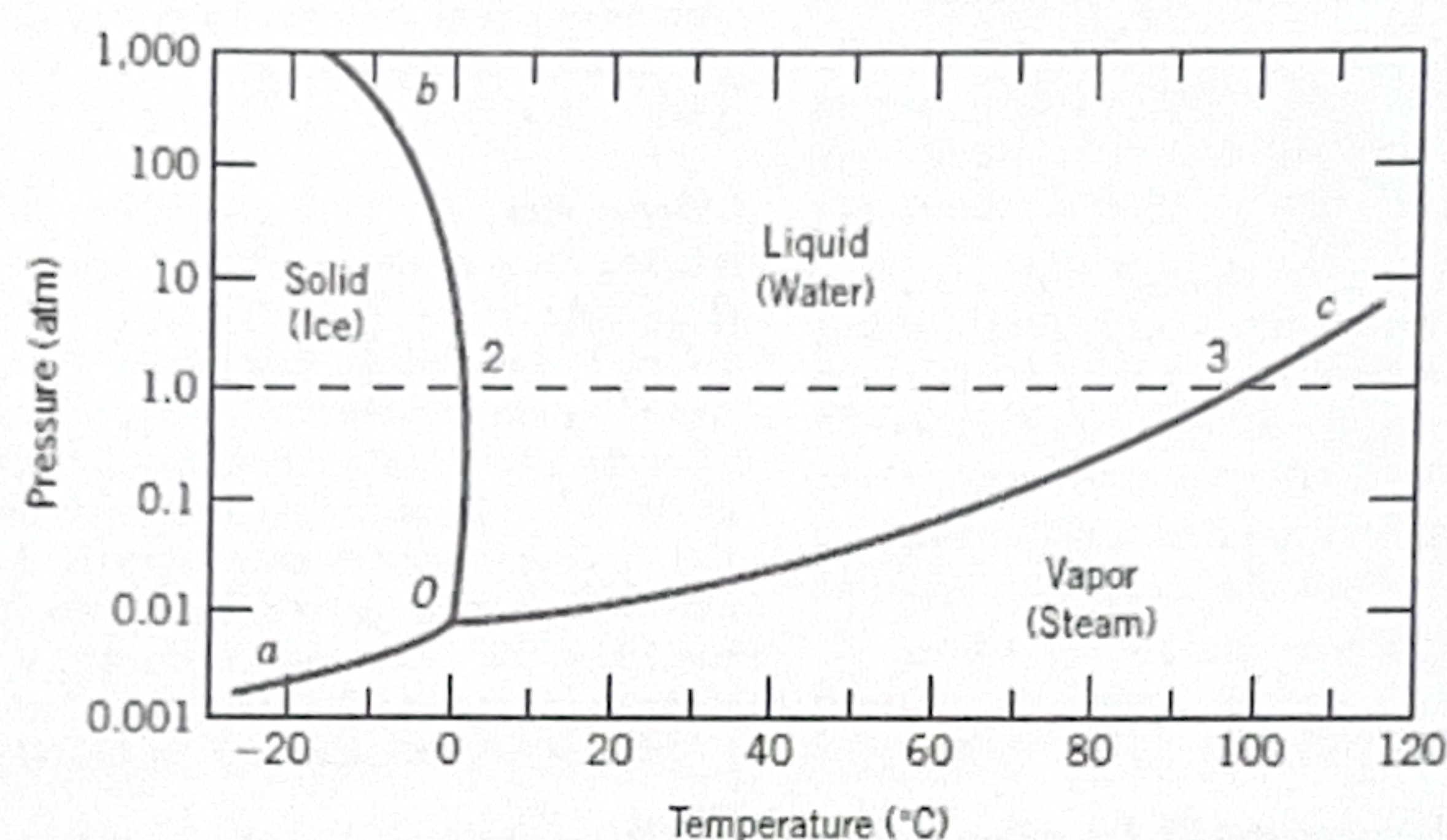
4. A reservoir fluid has a viscosity (μ) of 0.5 cp. It is flowing from a radius (r_e) of 2000 ft and a pressure (p_e) of 3500 psia to a well radius (r_w) of 0.5 ft and a pressure (p_{wf}) of 3200 psia. The bottom-hole pressure has been declining at a constant rate of 2 psi/day. The producing rate is a constant 850 stb/day. The oil formation volume factor is 1.1, and the total compressibility is 10^{-5} psi $^{-1}$.
- (1) What is the porosity thickness product (ϕh)?
 - (2) What is the permeability thickness product (kh)?
 - (3) What is the decline in the average reservoir pressure for 10 hours?
5. Well 1 and well 2 are drilled in an undeveloped reservoir. The distance between wells is 2500 ft. Well 1 is completed and produced at a constant rate of 540 stb/day for 52.5 days before well 2 is completed with initial production of 1080 stb/day. After well 1 has produced for 62.5 days at 540 stb/day, its production rate is reduced to 180 stb/day. Given the listed reservoir data, what is the pressure in well 2 after it has produced for 20 days (at this time well 1 has produced for 72.5 days)?

The reservoir data are as follows:

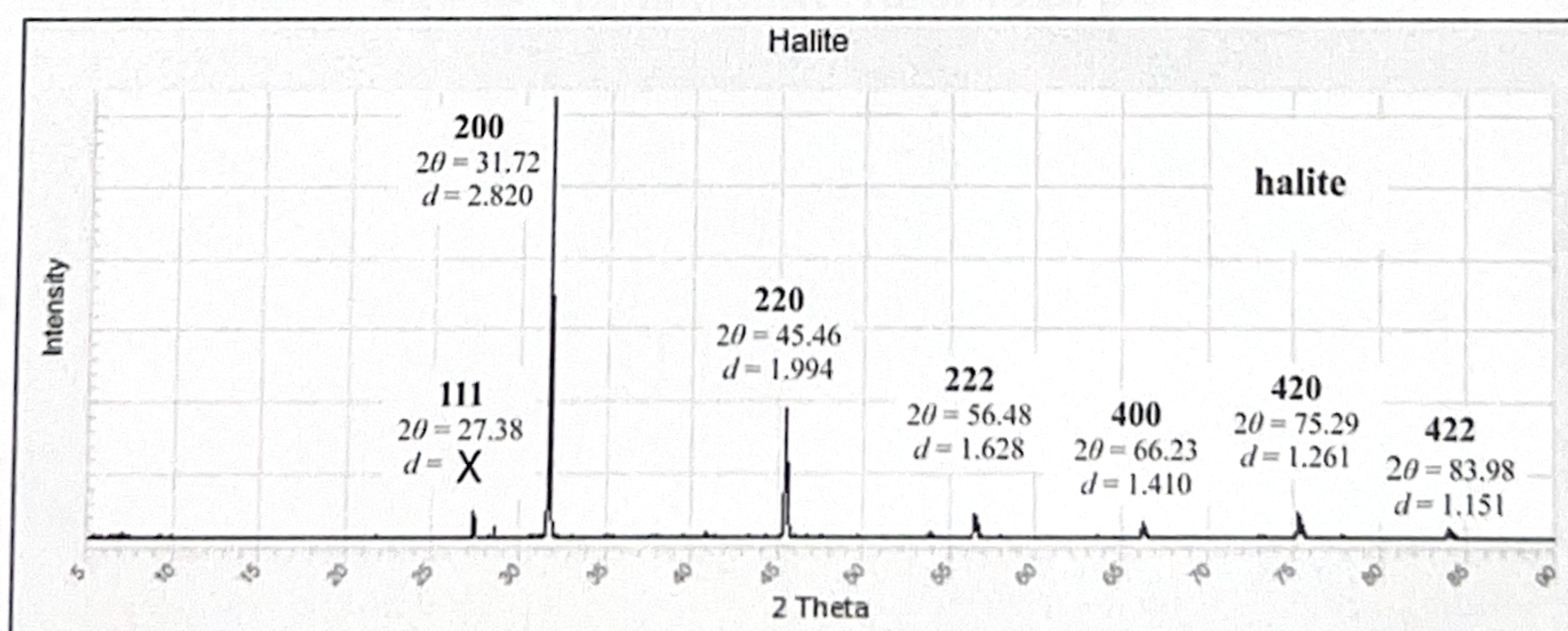
$$P_i = 3,000 \text{ psia}, Bo = 1.39 \frac{\text{bbl}}{\text{STB}}, \mu = 0.5 \text{ cp}, k = 100 \text{ md}, h = 14.1 \text{ ft},$$

$$c_t = 6.33 \times 10^{-5} \text{ psi}^{-1}, \phi = 0.20, r_w = 0.5 \text{ ft}, s = 0$$

1. Give the definition of a mineral. (10 pt)
2. Plot the unit cell geometries for the seven crystal systems and list their lattice parameters (axial and interaxial angles) (15 pt)
3. Explain and plot the Bowen's Reaction series. (10 pt)
4. Give electron configurations for the V^{3+} and S^{2-} ions. (^{16}S , ^{23}V) (10%)
5. Explain how Gibbs' Phase Rule applied to a point, curves, and fields of water P-T diagram. (10%)



6. (a) Using two parallel planes (periodic atomic arrangement) to explain Bragg's law by plotting the relationship among x-ray wavelength, interatomic spacing, and diffraction angle. (b) Write down Bragg's equation and use it to calculate the missing d value (x) in the below figure. (c) Explain the scientific meaning of the x and y axis. (d) Explain why there are no brackets describing the value like 200 or 220. ($Cu\ K\alpha$: $1.54\text{ \AA}$) (20%)



7. Read the following description about TALC and answer the questions

TALC— $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Crystallography. Triclinic; $\bar{1}$. Crystals rare. Usually tabular with rhombic or hexagonal outline. Foliated and in radiating foliated groups. When compact and massive, known as *steatite* or *soapstone*.

Cl; $a = 5.29, b = 9.17, c = 9.46 \text{ \AA}$; $\alpha = 90^\circ 28', \beta = 98^\circ 41', \gamma = 90^\circ 5'$; $Z = 4$. d_s : 9.34(10), 4.66(9), 3.12(10), 2.48(7), 1.870(4).

Physical Properties. *Cleavage* {001} perfect. Thin folia somewhat flexible but not elastic. *Sectile*. H 1 (will make a mark on cloth). *G* 2.7–2.8. *Luster* pearly to greasy. *Color* white, apple-green, gray, or silver-white; in soapstone often dark gray or green. *Translucent*. Greasy feel. *Optics* (–); $\alpha = 1.539, \beta = 1.589, \gamma = 1.589$; $2V = 6^\circ\text{--}30^\circ$. $Z = b$, $X \perp (001)$; $r > v$.

Composition and Structure. There is little variation in the chemical composition of most talc; pure talc contains MgO 31.7, SiO_2 63.5, H_2O 4.8%. Small amounts of Al or Ti may substitute for Si and Fe may replace some of the Mg which causes the color change from white to green. *Minnesotait*, $\text{Fe}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$, is common in low-grade metamorphic Precambrian iron deposits. Minnesotait has a modulated structure that is different from that of talc; it is probable that an almost complete solid solution exists between talc and minnesotait. The trioctahedral structure of talc is similar to that of dioctahedral pyrophyllite and consists of essentially neutral $t\text{--}o\text{--}t$ layers held together by weak residual bonds.

Diagnostic Features. Characterized by its micaceous habit, cleavage, softness, and greasy feel.

Occurrence. Talc is a secondary mineral formed by the alteration of magnesium silicates, such as olivine, pyroxenes, and amphiboles, and may be found as pseudomorphs after these minerals. Characteristically in low-grade metamorphic rocks, where, in massive form, *soapstone*, it may make up nearly the entire rock mass. It may also occur as a prominent constituent in schistose rocks, as in the talc schist.

In the United States, many talc or soapstone quarries are located along the line of the Appalachian Mountains from Vermont to Georgia. The major producing states are Montana, North Carolina, Texas, and Vermont.

Use. Most of the talc and soapstone produced is used in powdered form as an ingredient in paint, ceramics, rubber, insecticides, roofing, paper, cosmetics, and foundry facings. The most familiar use is in talcum powder. Talc is also used as an ornamental material for carving small objects.

Name. The name *talc* is of ancient and doubtful origin, probably derived from the Arabic word, *talk*.

Similar Species. *Minnesotait*, $\text{Fe}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$, the Fe-rich equivalent of talc. Occurs in Precambrian iron-formations.

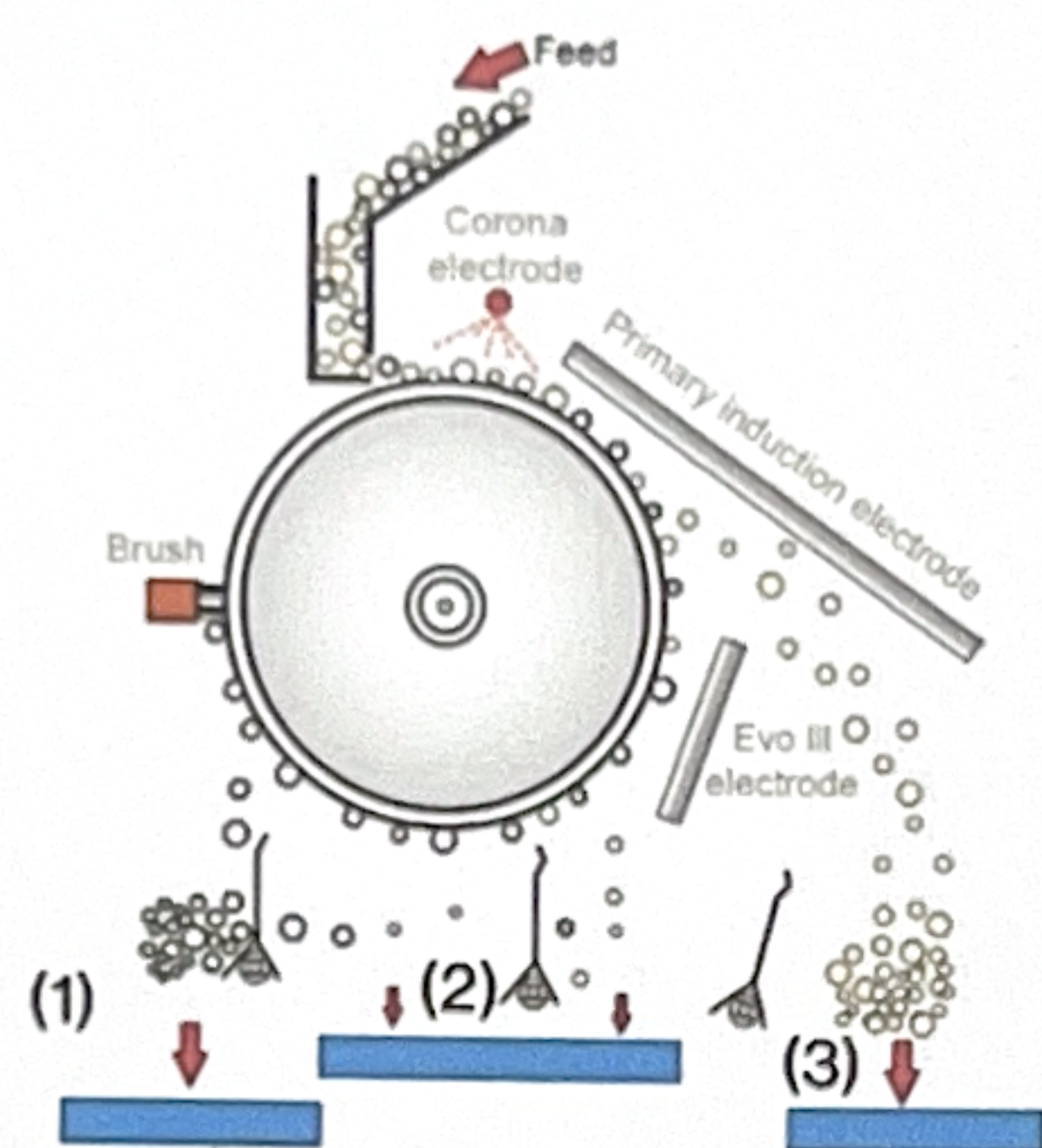
- (a) What does the symbol “G” in **Physical Properties** mean?
Please write down its definition. (5 pt)
- (b) Which of the following minerals are harder than TALC?
“gypsum, calcite, fluorite, apatite”(5 pt)
- (c) Why are the color and streak different? (5 pt)
- (d) Which mineral can have an almost completely solid solution with talc? (5 pt)
- (e) What does the “translucent” refer to (5 pt)

I. True-False Question (5 points each question)

- () Crushing mainly relies on Compressive Stress, while grinding relies on Shear Stress.
- () Jaw Crusher is usually use in primary crushers.
- () At low Reynolds numbers, flows tend to be dominated by laminar flow.
- () Coagulation is a physical procedure during the Dewatering process.
- () If something will be repelled by water, it is hydrophobic.
- () For a hydrophobic surface, induction time is long.

II. Multiple Choice Question (5 points each question)

- In the Ion Bombardment Electrical Separator, the particle distribution will be divided into three parts. What are (1), (2), and (3)?_____



i.

- (A) Conductor, Middling, and Nonconductor (B) Nonconductor, Middling, and Conductor (C) Middling, Conductor, and Nonconductor (D) Middling, Nonconductor, and Conductor
- Which system below is not the four basic subsystems of Automated Sorters?
(A) Particle presentation (B) Sensing (C) Electronic processing
(D) Comminution
 - _____ help produce the fine bubbles necessary to increase collision rates and to help maintain a reasonably stable.
(A) Frothers (B) Collectors (C) pH Regulators (D) Dispersants
 - Which of the following combination is the four major principles of resource processing?_____
(A) Comminution, Sizing, Concentration, and Metallurgy (B) Comminution, Classification, Concentration, and Dewatering (C) Crush, Sizing, Concentration, and Dewatering (D) Comminution, Sizing, Concentration, and Dewatering

5. During the comminution process, if a particle with 30 mm size, which Comminution Models below should it obey? _____

(A) Bond's Law (B) Newton's Law (C) Rittinger's Law (D) Kick's Law

6. _____ is the rotational speed where the centrifugal force on the grinding media equals the force of gravity, causing them to cling to the outer shell.

(A) Terminal Speed (B) Overspeed (C) Accelerated Speed (D) Critical Speed

7. Which mineral below has the highest χ ? _____

(A) Calcite (Diamagnetic) (B) Gypsum (Diamagnetic) (C) Pyrite (Paramagnetic) (D) Magnetite (Ferromagnetism)

III. Blank Filling Question (5 points each blank)

1. In the Dewatering process, _____ is associated with modification of particle surface charge to cause aggregation, while _____ involves addition of long-chain polymers that bind particles together.

2. An Electric Double Layer forms at interfaces, consisting of a charged surface and two distinct **ionic layers**: the inner layer called _____ (compact, adsorbed counterions) and the outer layer called _____, is a cloud of ions extending into the solution, screened by thermal and electrostatic forces.

3. Write down the formula of Rittinger's Law _____, Kick's Law _____, and Bond's Law _____ in the Energy-Based Comminution Models (X_F = Feed of the Particle; X_P =Product of the Particle).

4. Below a concentration of about _____% by volume, finely ground suspensions in water behave essentially as simple Newtonian fluids.

IV. Essay Question (5 points each question) (Round the number to the second decimal place)

1. Assume Bornite (density=5.2 g/cm³) and Chlorites (density=3.1 g/cm³) in a slurry proceeding with a hydraulic classification, the volume of solid in the slurry is 30% and the volume of light mineral in solid is 30%. Please calculate the value of hindered-settling ratio. _____

2. Write down the Formula of Work of Adhesion (Floatation).

3. An experimental ball mill with an inner diameter of 40 cm and a length of 30 cm and the diameter of grinding medium (grinding ball) is 2 cm. Please calculate the critical speed (rpm). (1ft=30.48cm)

1. Please define the terminologies of (a) Spectroscopy (b) Mass-spectroscopy and (c) Diffraction techniques. (10)
2. Fourier Transform Infrared Spectroscopy (FTIR) is commonly used to analyze organic materials. (a) Explain the role of "Fourier Transform" in this technique and how it is applied to convert the raw data into a usable spectrum. (b) Describe how to interpret the data obtained from FTIR, focusing on identifying functional groups and understanding the significance of the absorption peaks in the spectrum. (10)
3. Explain the working principle of Raman spectroscopy and how it differs from infrared (IR) spectroscopy in terms of vibrational mode selection (Raman-active vs. IR-active). Discuss the key differences between Raman and fluorescence signals, including their excitation mechanisms and spectral characteristics. If fluorescence occurs during Raman measurements, what strategies can be used to minimize or avoid it in order to obtain clear Raman spectra?
4. How does preferred orientation affect an X-ray diffraction (XRD) pattern in terms of peak intensities and missing reflections? Explain how the pattern may differ from a randomly oriented sample and why these changes occur. Finally, discuss experimental techniques to minimize the effects of preferred orientation. (15)
5. XRD peak broadening may be created by the size or strain effect. Please describe how "size" and "strain" effect generate to the full-width-half-maximum (FWHM) as a function of the incident angle of light. (5)
6. X-ray Photoelectron Spectroscopy (XPS) is a surface-sensitive technique used to analyze the elemental composition and chemical state of materials. (a) Explain the working principle of XPS, including how it detects elements and provides information on their chemical states. (b) What kind of information can be obtained from an XPS spectrum, and how can the binding energy shifts be used to interpret the chemical environment of elements in the sample? (15)
7. X-ray Fluorescence (XRF) and Energy Dispersive X-ray Spectroscopy (EDXS) are two techniques used for elemental analysis of materials. (a) Compare the working principles of XRF and EDXS, focusing on how each technique detects elements in a sample. (b) Highlight the differences in the type of data obtained from XRF and EDXS, and how the results can vary in terms of resolution and sensitivity. (10)
8. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) are two imaging techniques used to analyze materials at the nanoscale. (a) Compare the

working principles of SEM and TEM, focusing on how each technique forms an image.
(b) Discuss the differences in sample preparation for SEM and TEM, including the requirements for sample thickness, conductivity, and any coating or treatment needed before analysis. (15)

9. Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Spectroscopy (ICP) are commonly used techniques for measuring the concentration of elements in a solution. (a) Explain the working principles of AAS and ICP. (b) Compare the differences in the type of data obtained from these two methods, including sensitivity, detection limits, and the range of elements that can be analyzed. (10)

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