

(礦物部分共 50 分)

- 一、簡答題：下列是摘自礦物學課本對 *Opal* 之描述性資料，請在詳細閱讀後按照題號簡單且完整的回答本題的 10 個小題。(注意：除專有名詞外，照抄英文得零分)
【共 20 分】

OPAL— $\text{SiO}_2 \cdot n\text{H}_2\text{O}$

Crystallography. Generally amorphous. Massive; often botryoidal, stalactitic. Although X-ray studies indicate that much opal is essentially amorphous, it contains silica spheres in an ordered packing (see Structure, below).

Physical Properties. Fracture conchoidal. H 5-6. G 2.0-2.25. Luster vitreous; often somewhat resinous. Color colorless, white, pale shades of yellow, red, brown, green, gray, and blue. The darker colors result from impurities. Often has a milky or "opalescent" effect and may show a fine play of colors. Transparent to translucent. Some opal, especially *hyalite*, shows a greenish-yellow fluorescence in ultraviolet light. **Optics:** Refractive index 1.44-1.46.

Composition and Structure. $\text{SiO}_2 \cdot n\text{H}_2\text{O}$. The water content, usually between 4% and 9%, may be as high as 20%. The specific gravity and refractive index decrease with increasing water content.

Although opal is essentially amorphous, it has been shown to have an ordered structure. It is not a crystal structure with atoms in a regular three-dimensional array but is made up of closely packed spheres of silica in hexagonal and/or cubic closest packing. Air or water occupies the voids between the spheres. In common opal the domains of equal-size spheres with uniform packing are small or non-existent, but in precious opal, large domains are made up of regularly packed spheres of the same size. The sphere diameters vary from one opal to another and range from 1500 Å to 3000 Å. When white light passes through the essentially colorless opal and strikes planes of voids between spheres, certain wavelengths are diffracted and flash out of the stone as nearly pure spectral colors. This phenomenon has been described as analogous to the diffraction of X-rays by crystals. In X-ray diffraction the interplanar spacings (d) are of the same order of magnitude as the wavelengths of X-rays. In precious opal the spacings, determined by sphere diameters, are far greater but so are the wavelengths of visible light (4,000-7,000 Å). The different wavelengths that satisfy the Bragg equation are diffracted with change in the angle of incident light (θ). Because light is refracted when it enters precious opal, the equation must include the refractive index, μ ($= 1.45$), and the equation is written $n\lambda = \mu 2d \sin \theta$.

Diagnostic Features. Distinguished from microcrystalline varieties of quartz by lesser hardness and specific gravity and by the presence of water.

Varieties. *Precious opal* is characterized by a brilliant internal play of colors that may be red, orange, green, or blue. The body color is white, milky-blue, yellow, or black (*black opal*). *Fire opal* is a variety with intense orange to red reflectins.

Common Opal. Milk-white, yellow, green, red, etc., without internal reflections.

Hyalite. Clear and colorless opal with a globular or botryoidal surface.

Geyselite or Siliceous Sinter. Opal deposited by hot springs and geysers. Found about the geysers in Yellowstone National Park, Wyoming.

Wood Opal. Fossil wood with opal as the petrifying material.

Diatomite. Fine-grained deposits, resembling chalk in appearance. Formed by sinking from near the surface and the accumulation on the sea floor of the siliceous tests of diatoms. Also known as *diatomaceous earth* or *infusorial earth*.

Occurrence. Opal may be deposited by hot springs at shallow depths, by meteoric waters, or by low-temperature hypogene solutions. It is found lining and filling cavities in rocks and may replace wood buried in volcanic tuff. The largest accumulations of opal are as siliceous tests of silica-secreting organisms.

Precious opals are found at Caernowitza, Hungary; in Querétaro, Mexico; Queensland and New South Wales, Australia; and Brazil. Black opal has been found in the United States in Virgin Valley, Nevada. Diatomite is mined in several western states, principally at Lompoc, California.

Synthesis. Pierre Gilson in Switzerland has synthesized precious opal that is identical to natural material in chemical and physical properties, including a beautiful play of colors.

Use. As a gem. Opal is usually cut in round shapes, *en cabochon*. Stones of large size and exceptional quality are very highly prized. Diatomite is used extensively as an abrasive, filler, filtration powder, and in insulation products.

Name. The name *opal* originated in the Sanskrit, *upala*, meaning stone or precious stone.

1. *Opal* 的中文名稱是什麼？屬於哪一個晶系？
2. *Opal* 與「微晶質石英」類似但含水，此外還有哪兩項可鑑定的特性差異？
3. 有些 *Opal* 會在什麼光線下發出黃綠色螢光？*Opal* 的折射率是多少？
4. *Opal* 最高可含多少量的水？當含水量增加時，折射率會如何變化？
5. *Opal* 硬度是多少？比重是多少？
6. *Opal* 具有什麼斷口？什麼光澤？
7. 文中由生物矽質殼體組成的岩石叫什麼英文名稱？有什麼用途？
8. *Opal* 常在三種水內沈澱生成，除低溫湧升溶液外，還有哪兩種水？
9. 合成出與天然寶石級幾乎完全一樣的 *Opal* 是哪一國的什麼人？
10. *Opal* 名稱是從哪種文字來的？原本代表什麼意思？

- 二、(1) 根據以下資料繪製一幅斜長石在高溫部分 (1000°C 以上) 的雙成分相圖—
 (a) 斜長石在高溫的化學成分為一完全固溶體，介於鈣長石與鈉長石兩個端成分之間。
 (b) 鈣長石($\text{CaAl}_2\text{Si}_2\text{O}_8$)的熔點為 1557°C，鈉長石($\text{NaAlSi}_3\text{O}_8$)的熔點為 1100°C。
 (c) 當成分為 50%時，其 solidus 溫度約為 1280°C，而 liquidus 溫度約為 1450°C。

[註：應按比例在相圖上清楚標示橫軸、縱軸、端成份、溫度、solidus、liquidus、各相區所含的相名稱等。]【7分】

- (2) 請用「相律」(phase rule)計算在理論上，雙成分等壓系統中最多 (即當自由度為零時) 可以出現幾相共存？實際在斜長石相圖中最多有幾相共存？

[註：未列出計算式得 0 分；令 F 代表自由度，C 代表成分，P 代表相。]

【4分】

- (3) 根據此相圖，一個成分為 50%的熔融液體，溫度要降到幾度才會開始凝結出斜長石？剛凝出的斜長石晶體成分較接近鈣長石或鈉長石 (或剛好相等)？

【4分】

三、解釋名詞：【每題 5 分，共 15 分】

- (1) Calcite
- (2) Crystal classes
- (3) Miller indices

(岩石部分共 50 分)

- 一、下表 (Table 1) 是七種常見火成岩 (A 至 G) 的平均化學成分，若按各岩石英文名稱之字母順序排列為：Anorthosite, Basalt, Diorite, Gabbro, Granite, Granodiorite, 與 Syenite，而且已知七種之中只有 G 是火山岩，其他六種都是深成岩。請問：(1)這七種岩石的中文名稱分別為何？(2)A 至 G 各是哪一種火成岩？(3)如何根據下表之成分推論判斷出上述答案？【20 分】

TABLE 1

Average chemical compositions (wt%) of common igneous rock types

Component	A	B	C	D	E	F	G
SiO ₂	72.04	66.80	58.58	57.49	51.05	51.06	50.06
TiO ₂	0.30	0.54	0.96	0.82	0.63	1.17	1.87
Al ₂ O ₃	14.42	15.99	16.98	17.23	26.57	15.91	15.94
Fe ₂ O ₃	1.22	1.52	2.55	3.05	0.99	3.10	3.90
FeO	1.68	2.87	5.13	3.22	2.07	7.76	7.50
MnO	0.05	0.08	0.12	0.13	0.05	0.12	0.20
MgO	0.71	1.80	3.73	1.84	2.14	7.68	6.98
CaO	1.82	3.92	6.66	3.54	12.76	9.88	9.70
Na ₂ O	3.69	3.77	3.60	5.48	3.18	2.48	2.94
K ₂ O	4.12	2.79	1.81	5.03	0.62	0.96	1.08
P ₂ O ₅	0.12	0.18	0.29	0.29	0.69	0.24	0.34
No. of analyses	2485	885	872	517	104	1451	3796

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二、海洋與大陸地殼分別主要由何種岩石組成？並請分別描述它們的成因。【15分】

三、解釋名詞：【每題5分，共15分】

- (1) Petrography
- (2) Lithification
- (3) Metamorphism

試題隨卷繳回