

# **Geochemistry**

## **Introduction of geochemistry**

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**Lecture 2**

# Geochemistry

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- ▶ Defined is the science concerned with chemistry of the earth e.g. earth materials, minerals, and rocks. It deals with:
    - i. The determination of the relative and absolute abundance of the elements in the earth.
    - ii. The study of the distribution and migration of the individual elements in the various parts of the earth (atmosphere, hydrosphere, crust, and etc) with the object of discovering principles governing this distribution and migration.
    - iii. The application of geochemistry principles and information in solving human needs.
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# V. M. Goldschmidt

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- ▶ Victor Moritz Goldschmidt, Swiss mineralogist, is regarded as the founder of modern geochemistry.
  - ▶ He characterized geochemistry with the following:
    1. The major task of geochemistry is to investigate the composition of the earth as a whole and of its various components and to uncover the laws that control the distribution of the various elements.
    2. To solve these problems, the geochemist needs a comprehensive collection of analytical data of terrestrial material, i.e. rocks, waters, and atmosphere.
    3. He uses analyses of meteorites, astrophysical data about composition of other cosmic bodies and geophysical data about the nature of the earth's inside.
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# The main focus of geochemistry

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- ▶ Understand the principles governing the distribution and re-distribution of elements, ionic species and isotope ratios in earth materials, so that we can interpret the formation of mineral assemblages: conditions (pressure, temperature, and etc), processes (magmatic crystallization, weathering, chemical precipitation, metamorphism, and etc), and even the age.
- ▶ Predict changes in mineral assemblages (minerals, concentrations of elements, isotopic ratios) if a given mineral assemblage is subjected to different conditions (pressure, temperature, interaction with a fluid, and etc).
- ▶ Geochemistry plays an important role in forecasting the quality of crude oil in the accumulation.



# Branches of geochemistry

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- i. **Isotope geochemistry:** determination of the relative and absolute concentrations of the elements and their isotopes in the earth's surface.
  - ii. **Cosmochemistry:** analysis of the distribution of elements and their isotopes in the cosmos.
  - iii. **Biogeochemistry:** focuses on the effects of life on the chemistry of the earth.
  - iv. **Organic geochemistry:** a study of the role of processes and compounds that are derived from living or once-living organism.
  - v. **Hydrogeochemistry:** understanding the role of various elements in watersheds.
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# Branches of geochemistry

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- vi. Environmental and exploration geochemistry:** application to environmental, hydrological and mineral exploration studies.
  - vii. Gaseous geochemistry:** studies the chemistry of the atmosphere of the Earth and that of other planets. Types of issues that atmospheric science has tackled include acid rain, ozone depletion, photochemical smog, greenhouse gases and global warming.
  - viii. Trace and elemental geochemistry:** present in concentrations  $<0.1\%$ , expressed in ppm or ppb, and analysis by XRF, ICP-MS. Ex. Ga, Cr, Mo, Li, Ni, Co, Cu, Zr, Y, La, Sr, Ba, Rb, ...etc.
  - ix. Metamorphic and igneous-rock geochemistry**
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# The field application of geochemistry

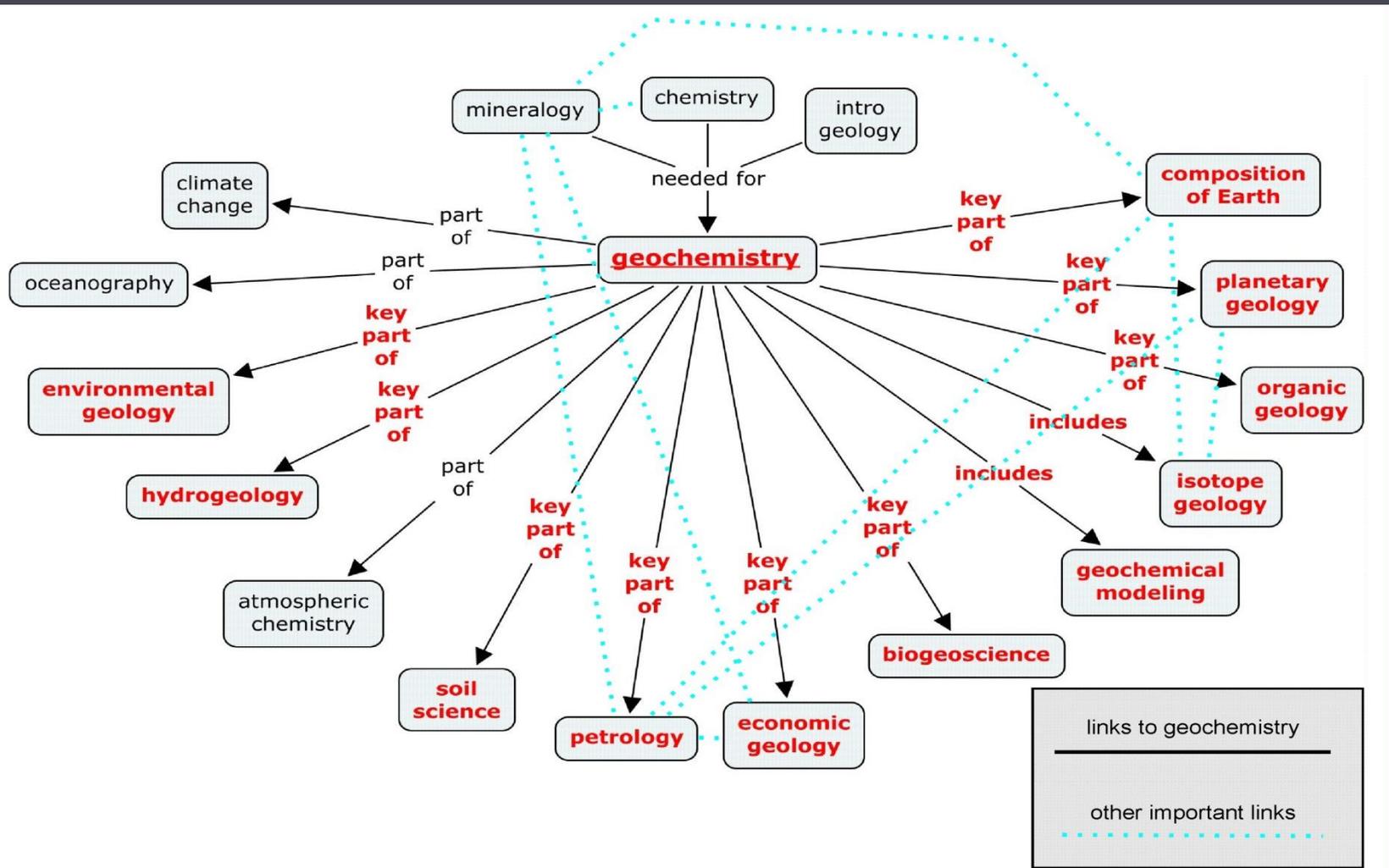
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▶ Geochemistry has applications in many fields such as:

1. Medicine
2. Climate
3. Environment
4. Water quality
5. Petroleum
6. Mineral deposits
7. Age dating
8. Ore exploration
9. Industrial geochemistry
10. Geochemical engineering
11. Etc.



# The field application of geochemistry



# Analytical instrumentation

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- ▶ Inductively-coupled plasma -Atomic Emission Spectroscopy (ICP-AES)
- ▶ Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)
- ▶ X-ray fluorescence (XRF)
- ▶ Stable-isotope mass spectrometers
- ▶ Fourier transform infrared spectroscopy (FTIR)
- ▶ Fully automated electron microprobe
- ▶ X-ray diffractometer (XRD)
- ▶ Scanning electron microscope (SEM)
- ▶ High purity germanium detector (HPGe)
- ▶ Other facilities



# Goldschmidt's classification of elements

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- ▶ This classification was developed by V. Goldschmidt, is a geochemical classification which groups the chemical elements according to their preferred host phases (affinity) into:
  1. **Lithophile (rock-loving)**
  2. **Siderophile (iron-loving)**
  3. **Chalcophile (sulphur-loving)**
  4. **Atmophile (gas-loving)**
- ▶ **Biophile** (elements of living organisms), **Hydrophile** (water-loving), **Thalassophile** (seawater elements) are outside this classification.



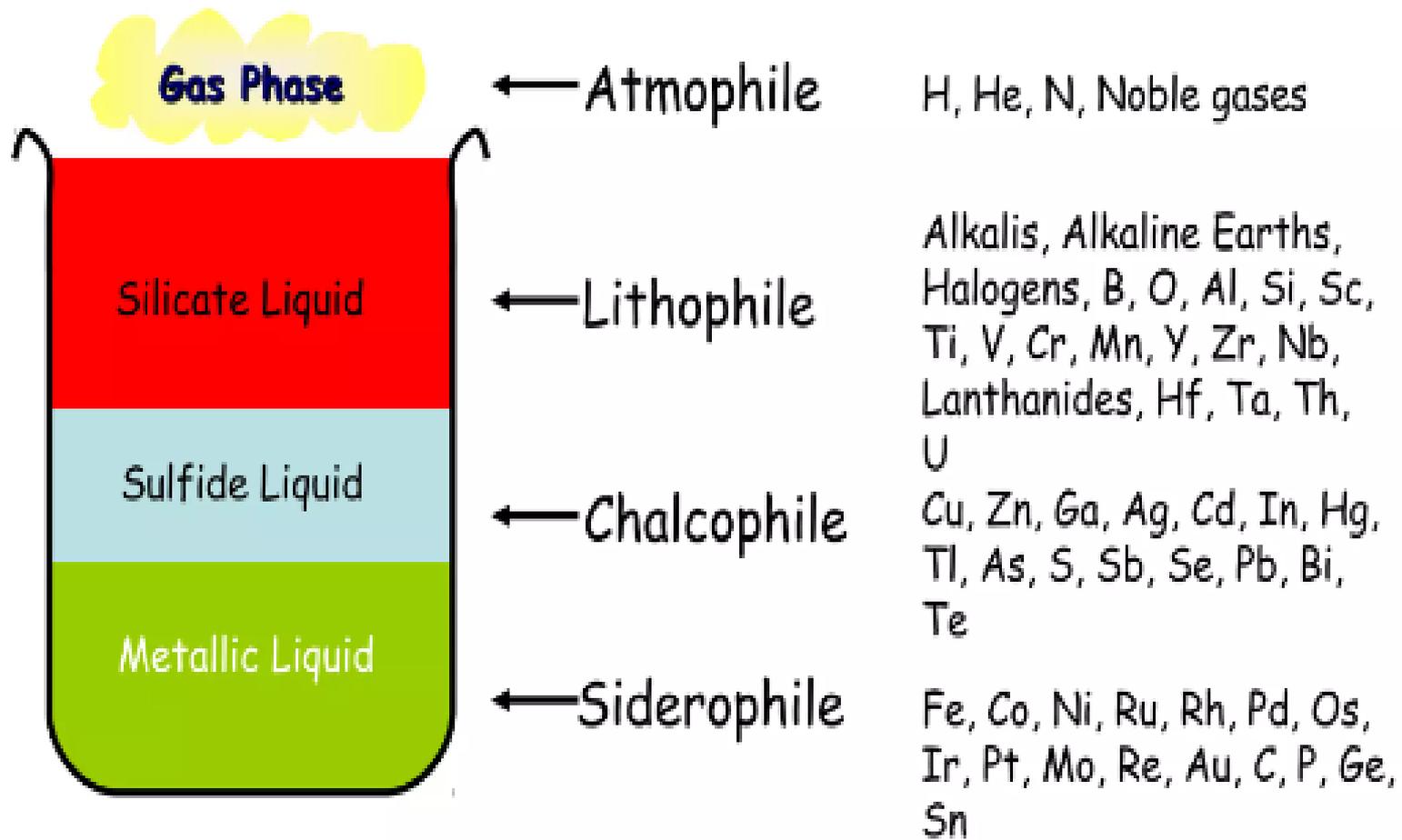
# Goldschmidt's classification of elements

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- ▶ **Chemical affinity** is the electronic property by which dissimilar chemical species are capable of forming chemical compounds or Affinity is the tendency of a molecule to associate with another.
- ▶ **Chemical affinity** can also refer to the tendency of an atom or compound to combine by chemical reaction with atoms or compounds of unlike composition.
- ▶ Some elements have affinities to more than one phases.



# Goldschmidt's classification of elements



# Lithophile

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- ▶ Lithophile elements mainly consist of the **highly reactive metals of the s- and f-blocks**. They also include a **small number of reactive nonmetals**, and the **more reactive metals of the d-block** such as **titanium, zirconium and vanadium**. Lithophile literally means “**rock-loving**”.
- ▶ Most lithophile elements form very stable ions. The few that do not, such as silicon, phosphorus and boron, form extremely strong covalent bonds with oxygen. Their strong affinity for oxygen causes lithophile elements to associate very strongly with silica, forming relatively low-density minerals that thus float to the crust.
- ▶ The **more soluble minerals formed by the alkali metals tend to concentrate in seawater or extremely arid regions where they can crystallize**. The **less soluble lithophile elements are concentrated on ancient continental shields where all soluble minerals have been weathered**.



# Siderophile

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- ▶ Siderophile elements are the **high-density transition metals that tend to bond with metallic iron in the solid or molten state**. Siderophile means "**iron-loving**".
- ▶ Most siderophile elements have practically no affinity whatsoever for oxygen. They form stronger bonds with carbon or sulfur, but even these are not strong enough to separate out with the chalcophile elements.
- ▶ Siderophile elements are bound through metallic bonds with iron in the dense layer of the Earth's core where pressures may be high enough to keep the iron solid.
- ▶ Because they are concentrated in the dense core, siderophile elements are known for their rarity in the Earth's crust. Most of them have always been known as **precious** because of this. They are concentrated in the mantle and core.



# Chalcophile

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- ▶ Chalcophile elements are those **metals** (sometimes called "**poor metals**") and **heavier nonmetals** that have a **low affinity for oxygen and prefer to bond with sulfur as highly insoluble sulfides**. Chalcophile literally means "**copper-loving**", but is taken to mean "**sulfur-loving**" or "**ore-loving**" by various sources.
- ▶ Because these sulfides are **much denser than the silicate minerals** formed by lithophile elements, chalcophile elements separated below the lithophiles at the time of the first crystallisation of the Earth's crust. This has led to their depletion in the Earth's crust, though because the minerals **they form are nonmetallic**, this depletion has not reached the levels found with siderophile elements.



# Atmophile

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- ▶ Atmophile elements are defined as those that are found chiefly or exclusively in the form of **gases**. The **noble gases** do not form stable compounds and occur as **monatomic gases**.
- ▶ Whilst **nitrogen**, although it does not have a stable configuration for its individual atoms, forms a **diatomic molecule** so strong. Molecular nitrogen which has come to **form four-fifths of the Earth's atmosphere**.
- ▶ **Carbon** is also classed as an atmophile because it forms **very strong multiple bonds with oxygen in carbon monoxide and carbon dioxide**. The latter is the **fourth-largest constituent of the Earth's atmosphere**, whilst **carbon monoxide occurs naturally in volcanoes and has a residence time in the atmosphere of a few months**



# Goldschmidt's classification of elements

		<table border="1"> <tr> <td style="background-color: yellow;">Atmophile</td> <td style="background-color: cyan;">Siderophile</td> </tr> <tr> <td style="background-color: red;">Lithophile</td> <td style="background-color: white;">Artificial</td> </tr> <tr> <td style="background-color: orange;">Chalcophile</td> <td></td> </tr> </table>										Atmophile	Siderophile	Lithophile	Artificial	Chalcophile													
Atmophile	Siderophile																												
Lithophile	Artificial																												
Chalcophile																													
		IA	IIA												IIIA	IVA	VA	VIA	VIIA	VIIIA									
1		1 H													2 He														
2		3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne										
3		11 Na	12 Mg	III B	IV B	V B	VII B	VIII B	VIII B		IB	IIB	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar											
4		19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr										
5		37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe										
6		55 Cs	56 Ba											72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
7		87 Fr	88 Ra											104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt										
Lanthanides		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu													
Actinides		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr													