University of Badji-Mokhtar Annaba
Faculty of Technology
Department 2 nd year (2025-2026)

Exam Solutions in mineral chemistry

Exercise 1 (3pts)

1. The main steps of the Haber–Bosch process for producing ammonia are:

1. Production of reactants: **0.5**

- **Nitrogen (N_2):** Obtained by fractional distillation of air (air contains about 78% nitrogen).
- **Hydrogen (H_2):** Obtained by methane reforming (CH_4):
  $CH_4 + H_2O \rightarrow CO + 3H_2$
  Carbon monoxide (CO) is then converted int o carbon dioxide (CO_2) and removed.

2. Compression and heating of gases: **0.5**

Nitrogen and hydrogen gases are compressed to high pressure and heated to 400–500 °C.

3. Synthesis in the reactor: **0.5**

The gases pass over an iron catalyst bed. The reaction is partial, but the produced ammonia is rapidly liquefied to promote conversion.

4. Recovery and recycling: **0.5**

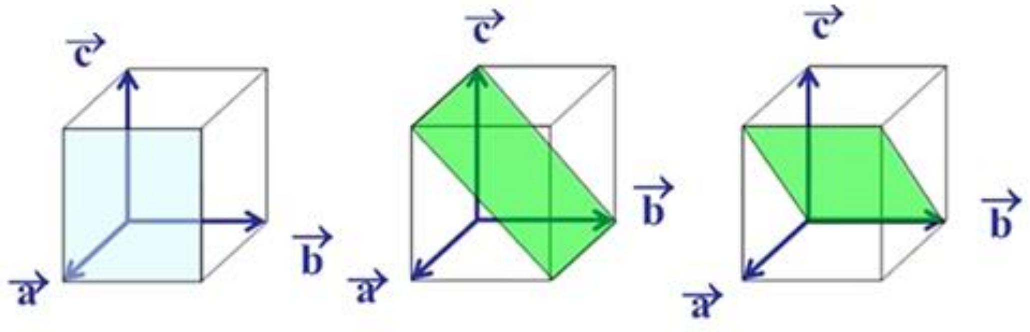
Ammonia is separated by cooling, and the unreacted gases (N_2, H_2) are recycled back into the reactor.

2. Application of ammonia in industry: **1**

Ammonia is used to manufacture fertilizers such as ammonium nitrate.

Exercise 2 (7pts)

I.**The following lattice planes (Miller indices (hkl)). The unit cells are cubic.** **1x3**



a= 1 h= 1 b= ∞ k= 0 c= ∞ l= 0 donc le plan est : (1 0 0)	a= ∞ h= 0 b= 1 k= 1 c= 1 l= 1 donc le plan est : (0 1 1)	a= 1 h= 1 b=∞ k= 0 c=1 l= 1 donc le plan est : (1 0 1)

II.

1. Calculation of the total number of atoms present in the crystal

$$n = \frac{m}{M} = \frac{N}{N_A}$$

$$N = \frac{mN_A}{M}$$

$$N = \frac{100 \times 6{,}023 \times 10^{23}}{183{,}84}$$

$$N = 3{,}28 \times 10^{23} atoms$$ **0.5**

2. Determination of the total number of unit cells forming the crystal
   - Calculation of the number of atoms in one unit cell (multiplicity calculation)

M = NS.1/8 + NA.1/4 + NF.1/2 + NI.1 **0.5**

$$M = NS\frac{1}{8} + NA\frac{1}{4} + NS\frac{1}{2} + NI$$

$$M = 8 \times \frac{1}{8} + 1 \ = 2\ atomes/maille$$ **0.5**

Each unit cell contains **2 atoms**.

1 unit cells ⟶ 2 atoms

N unit cells ⟶ 4,738 x 10^{22} atoms

$$N_{maille} = \frac{1 \times 3{,}28 \times 10^{23}}{2}$$

$$N_{maille} = 1{,}64 \times 10^{23} \text{ unit cell}$$ **0.5**

3. Calculation of the packing efficiency (compacity, C)

$$C = \frac{V_{\text{occupied by atoms in the unit cell}}}{V_{\text{unit cell}}}$$ **0.5**

$$C = \frac{z\ \frac{4}{3}\pi r^3}{a^3}$$

$$C = \frac{4 \times \frac{4}{3} \times 3{,}14 \times r^3}{(\frac{4r}{\sqrt{3}})^3}$$

$$C = 0{,}68$$ **0.5**

4. Calculation of the packing fraction (τ)

$$\tau = C \times 100$$ **0.25**

$$\tau = 0{,}68 \times 100$$

$$\tau = 68\%$$ **0.25**

The percentage of void in the unit cell.

$$\%\ de\ vide\ = 100 - \ \tau$$ **0.25**

$$\%\ de\ vide\ = 100 - \ 68$$

$$\%\ de\ vide\ = 32\ \%$$ **0.25**

Exercise 3 **(5pts)**

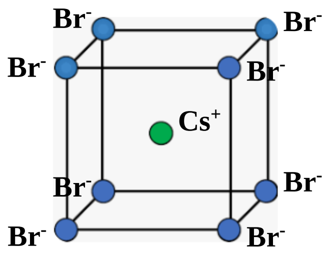
1. **Cesium Bromide (CsBr) – Cubic Crystal Structure**

Nature of the bonding: The bonds between Cs and Br atoms are **ionic**. **1**

2. **Representation of the unit cell:**

Since r^+=196pm < r^-= 265pm , the **Br^- ions occupy the corners of the cube**, and the Cs^+ ions occupy the **center of the cube**. **1**

Calculation of the radius ratio: **0.5**



$$\frac{r^+}{r^-} = \frac{196}{265} = 0{,}739 > 0{,}732$$ **0.5**

According to **Pauling's rules**, the crystal site of Cs^+ is **cubic**. **1**

3. **Coordination number (CN) of ions:**
   - For Br^-: : $Br^- / Cs^+ = 8$ **0.5**
   - For Cs^+: $Cs^+/Br^- = 8$ **0.5**

<u>Exercise 4</u> (5pts)

Consider the following two atoms: $_5$B and $_{13}$Al.

1. Position in the periodic table (column, period, group):

- **Boron (B, Z = 5):** $1s^2 2s^2 2p^1$ **0.25**
  - **Period:** 2 **0.25**
  - **Group:** III_A **0.25**
  - **Column:** 13 **0.25**
- **Aluminum (Al, Z = 13):** $1s^2 2s^2 2p^6 3s^2 3p^1$ **0.25**
  - **Period:** 3 **0.25**
  - **Group:** III_A **0.25**
  - **Column:** 13 **0.25**

2. Family of the elements:

Both boron and aluminum belong to the **boron family** **1**

3. Possible oxidation states of boron in compounds:

B_2O_3 (boron trioxide): Boron has an oxidation state of **+3** **0.5**

BF_3 (boron trifluoride): Boron has an oxidation state of **+3** **0.5**

4. Applications of aluminum (Al) and boron (B):

- **Aluminum (Al):** **0.5**
  1. Used in making **lightweight materials for the aerospace and automotive industries**
  2. Used in **packaging materials**, such as aluminum foil and cans
- **Boron (B):** **0.5**
  1. Used in **borosilicate glass** (heat-resistant glass)
  2. Used as a **doping element in semiconductors** or in **boron-containing detergents and fertilizers**