

## Group II B

8. Zn
- <sup>2+</sup>
- :
- a*
- sites and possibly
- c*
- sites

{Gd <sub>3</sub> }[Zn <sub>2</sub> ](GaGe <sub>2</sub> )O <sub>12</sub> <sup>43</sup>	<i>a</i> = 12.464
{MnGd <sub>2</sub> }[ZnMn](Ge <sub>3</sub> )O <sub>12</sub> <sup>43</sup> (probable distribution)	12.427
{NaCa <sub>2</sub> }[Zn <sub>2</sub> ](V <sub>3</sub> )O <sub>12</sub> <sup>74</sup>	12.439

See also 1.

9. Cd
- <sup>2+</sup>
- :
- c*
- sites

{CdGd <sub>2</sub> }[Mn <sub>2</sub> ](Ge <sub>3</sub> )O <sub>12</sub> <sup>43</sup>	<i>a</i> = 12.473
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See also Tables 3 and 4.

## Group III B

10. Sc
- <sup>3+</sup>
- :
- a*
- sites

Examples of end-member garnets containing Sc<sup>3+</sup> ions are given in Tables 3 and 4. However, the earliest published report of substitution of Sc<sup>3+</sup> ion in the iron garnets is given in Ref. 73. Some systems studied involving Sc<sup>3+</sup> ion are:

{Y <sub>3</sub> }[Fe <sub>2-x</sub> Sc <sub>x</sub> ](Fe <sub>3</sub> )O <sub>12</sub> <sup>7,59,78</sup>
{Gd <sub>3</sub> }[Fe <sub>2-x</sub> Sc <sub>x</sub> ](Fe <sub>3</sub> )O <sub>12</sub> <sup>75</sup>
{Y <sub>3-y</sub> Ca <sub>y</sub> }[Sc <sub>x</sub> Fe <sub>2-x</sub> ](Si <sub>y</sub> Fe <sub>3-y</sub> )O <sub>12</sub> <sup>7</sup>
{Gd <sub>2</sub> Y}[Fe <sub>2-x</sub> Sc <sub>x</sub> ](Fe <sub>3</sub> )O <sub>12</sub> <sup>75</sup>

11. Y
- <sup>3+</sup>
- :
- c*
- and
- a*
- sites

See Tables 4 and 5 and the various other examples given in this survey. Also see previous discussion of solid solutions in the Y<sub>2</sub>O<sub>3</sub>-Ga<sub>2</sub>O<sub>3</sub> and Y<sub>2</sub>O<sub>3</sub>-Al<sub>2</sub>O<sub>3</sub> systems.

12. Rare earths: all the trivalent rare-earth ions except that of Pm are known to enter *c* sites in the garnets. Pm<sup>3+</sup> should also, but as far as I know the rarity of Pm has precluded its being tried. Replacement of at least 1% of the yttrium by Ce<sup>3+</sup> in YFe garnet has been recently proved<sup>79</sup>. (Actually, it should be possible to replace 30% of the Y<sup>3+</sup> by Ce<sup>3+</sup> ion.) The smaller trivalent ions of Lu, Yb, Tm, Er, Ho, and Dy also enter *a* sites as shown in Table 4. Substitution of Yb<sup>3+</sup> (in small amount) for Fe<sup>3+</sup> in

<sup>78</sup> M. A. GILLES AND S. GELLER, Substitution for iron in yttrium iron garnet. *J. Appl. Physics* 29 (1958) 380-381.

<sup>79</sup> K. A. WICKERSHEIM AND R. A. BUCHANAN, Optical studies of exchange in substituted garnets. *J. Appl. Physics* 38 (1967) 1048-1049.

YFe garnet has been indicated by microwave resonance absorption measurement<sup>80</sup>. Various mixed rare earth iron garnet systems have also been studied.

## Group III A

13. Al
- <sup>3+</sup>
- :
- a*
- and
- d*
- sites

Many examples of end-member garnets containing Al<sup>3+</sup> ion are given in Tables 3-5. In addition, several solid-solution systems including the Al<sup>3+</sup> ion have been studied; some examples are:

{Y <sub>3</sub> }Fe <sub>5-x</sub> Al <sub>x</sub> O <sub>12</sub> <sup>7,59,78</sup>
{Gd <sub>3</sub> }Fe <sub>5-x</sub> Al <sub>x</sub> O <sub>12</sub> <sup>75</sup>
Ca <sub>3</sub> Al <sub>2</sub> Si <sub>3</sub> O <sub>12</sub> -Y <sub>3</sub> Fe <sub>2</sub> Fe <sub>3</sub> O <sub>12</sub> <sup>36</sup>
Mn <sub>3</sub> Al <sub>2</sub> Si <sub>3</sub> O <sub>12</sub> -Y <sub>3</sub> Al <sub>2</sub> Al <sub>3</sub> O <sub>12</sub> <sup>40</sup>
Mn <sub>3</sub> Al <sub>2</sub> Si <sub>3</sub> O <sub>12</sub> -Y <sub>3</sub> Fe <sub>2</sub> Fe <sub>3</sub> O <sub>12</sub> <sup>36</sup>
{Bi <sub>0.25</sub> Y <sub>2.75</sub> }Fe <sub>5-x</sub> Al <sub>x</sub> O <sub>12</sub> <sup>81</sup> .

14. Ga
- <sup>3+</sup>
- :
- a*
- and
- d*
- sites

Many examples are given in Tables 3-5 and elsewhere in this survey. One of the most extensively studied systems is Y<sub>3</sub>Fe<sub>5-x</sub>Ga<sub>x</sub>O<sub>12</sub><sup>27</sup>, a detailed discussion of which will be given elsewhere in this paper.

15. In
- <sup>3+</sup>
- :
- a*
- sites

The first introduction of In<sup>3+</sup> ion into YFe garnet was reported in 1958<sup>78</sup>. Examples of complete *a* site occupation are given in Tables 3 and 4. There is a possibility that In<sup>3+</sup> ions will enter *c* sites.

## Group IV B

16. Ti
- <sup>4+</sup>
- : prefers
- a*
- sites but enters
- d*
- sites

{Ca <sub>3</sub> }[TiNi](Ge <sub>3</sub> )O <sub>12</sub>	<i>a</i> = 12.341 <sup>74</sup> , 12.32 <sup>43</sup> Å
{Ca <sub>3</sub> }[TiCo](Ge <sub>3</sub> )O <sub>12</sub>	12.356 <sup>74</sup> , 12.35 <sup>43</sup>
{Y <sub>3-x</sub> Ca <sub>x</sub> }Ti <sub>x</sub> Fe <sub>5-x</sub> O <sub>12</sub> <sup>66,82</sup>	

<sup>80</sup> J. F. DILLON, JR., J. P. REMEIKI AND L. R. WALKER, Yb<sup>3+</sup> on octahedral sites in YIG. *Bull. Amer. Phys. Soc.* [2] 11 (1966) 378.

<sup>81</sup> S. GELLER, H. J. WILLIAMS, R. C. SHERWOOD AND G. P. ESPINOSA, Bismuth substitution in yttrium iron aluminum garnets. *J. Appl. Physics* 35 (1964) 1754-1756.

<sup>82</sup> S. GELLER, R. C. SHERWOOD, G. P. ESPINOSA AND H. J. WILLIAMS, Substitution of Ti<sup>4+</sup>, Cr<sup>3+</sup> and Ru<sup>4+</sup> ions in yttrium iron garnet. *J. Appl. Physics* 36 (1965) 321.