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The 4d4f configuration in YII

ABSTRACT

Hollow-cathode spectra of yttrium have been registered in the wavelength region 1000Å - 28000Å. New high-lying levels, belonging to e.g. the 4dnf configurations (n = 4-8), have been established. The levels of the 4d4f configuration, which are reported here, give strong lines at 1600Å in transitions to the low even configurations $5s^2$, 5s4d and $4d^2$. This is due to a selective excitation by the charge-exchange reaction between Ar^+ and Y which effectively populates the 4d4f levels of YII when Ar is used as a carrier gas in the hollow-cathode lamp.

INTRODUCTION

Singly ionized yttrium is the second member of the SrI isoelectronic sequence. Alike SrI, YII has the groundconfiguration $5s^2$, while higher members of the sequence have the groundconfiguration $4d^2$. In YII the two lowest excited configurations 4d5s and $4d^2$ lie very close to $5s^2$. This structure makes the system a good example of the competition between 4d- and 5s-orbitals regarding the lowest energy.

The first analysis of Y was done by Meggers and Russel in 1929 (Meggers, 1929). They established 61 energy levels of YII and 145 levels of YI. In a later study of Y, (Palmer, 1977) improved level values of YI and YII were given together with 47 new levels of YI. However, no additions to the old analysis of YII were done. The present analysis of YII has improved the earlier known energy levels, and led to the establishment of 134 new high-lying levels.

This report describes parts of the analysis that can be of astrophysical interest e.g. the strong 4d-4f transitions.

EXPERIMENT

The UV spectra (1000Å-2400Å) were registered by use of the 10.7 m normal incidence spectrograph at NIST, Gaithersburg, Md. The strongest YII spectrum was obtained when the hollow-cathode was run in a continuous mode with Ar, at a pressure of 0.2 Torr, as a carrier gas. Spectra were also registered with Ne, at a pressure of 1.0 Torr, as a carrier gas. A comparison of the spectrograms from these different runs, shows that the YII lines appear much stronger in the hollow-cathode run with Ar. Figure 1, which shows the region 1580Å-1630Å with some of the strongest 4d-4f transitions, is a good illustration of this phenomenon which we refer to as charge-transfer (Johansson, 1978).

Fig. 1. Hollow cathode spectra of Y run with a) Ar and b) Ne as a carrier gas.

In this case the charge-transfer process is evident, as the excitation potential for the 4d4f-levels is approximately 9 eV, which, together with the ionization energy for YI, well match the ionization energy for ArI (fig. 2). The enhancement of the YII lines thus makes them easy to distinguish from YI, YIII and carrier gas lines in a comparison with Y-Ne spectra.

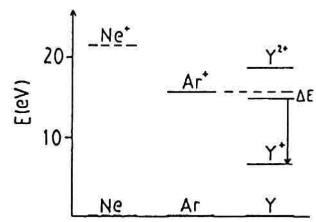

Fig. 2. The charge-transfer reaction :

$Y + Ar^+ \rightarrow Y^{+*} + Ar + \Delta E$

The wavelength region 2100Å-28000Å has later been covered in order to enable a complete analysis of YII. (To be reported elsewhere.) Those spectra were registered by use of the 1 m Fourier Transform Spectrometer (FTS) at Kitt Peak National Observatory, Tucson, Az.

The hollow-cathode used in that experiment had a slightly different geometry than the one used at NIST. Unexpectedly, this meant that the hollow-cathode could not be run with

100% Ne as a carrier gas. The only way to make the light source burn with Ne, was to mix equal parts of Ne and Ar. Consequently, the easy method of distinguishing YII from YI and YIII, applied in the UV, is not so powerful here.

ANALYSIS

In this analysis, 82 lines in the wavelength region 1387Å-1849Å, have been identified. They connect the 19 new 4d4f levels with the $5s^2$, 4d5s and $4d^2$ levels. The missing 4d4f $^3P_0$ does only have two allowed transitions to the lowest even configurations. There are a number of plausible candidates for this level, which at this moment cannot be established unambiguously.

On the spectrograms, most of the strong 4d-4f transitions can clearly be seen to form a prominent group around 1600Å. The estimated error in the wavelengths is around ±0.002Å. Some of the strongest lines with very broad profiles have a somewhat larger error. This means that the energy levels established by use of UV-lines, have uncertainties as big as $\pm 0.3 cm^{-1}$.

The level values given in Table 1, have a much higher accuracy, which has been obtained by means of the FTS data. After being established by the $4d^2$-4d4f transitions in the UV, the 4d4f levels have been connected to the ground state via the 4d5d and 4d5p configurations through FTS measurements. The estimated error in the energies is less than $\pm 0.005 cm^{-1}$.

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Table 1. The 4d4f configuration of YII

Term	J	Level(cm^{-1})
^1G	4	69746.436
^3F	2	69901.161
	3	69977.806
	4	70415.225
^3H	4	70081.961
	5	70285.156
	6	70786.579
^3G	3	70267.625
	4	70787.460
	5	70913.028
^1D	2	70594.407
^3D	1	70619.987
	2	70977.232
	3	70845.933
^1F	3	71178.484
^3P	0	
	1	71550.657
	2	71448.656
^1H	5	71635.626
^1P	1	72079.803

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