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The spin polarization and differential cross sections in the elastic scattering of electrons by alkali metal atoms

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Abstract. The spin polarization, depolarization ratio and differential cross sections are calculated for the elastic scattering of electrons by lithium, sodium, potassium and caesium atoms for the impact electrons energies below the excitation threshold.

The phase shifts evaluated in the two-state close coupling approximation (Karule 1965) are used throughout.

1. Introduction

In a previous paper (Karule 1965) we calculated the total and partial cross sections for the elastic scattering of electrons by alkali atoms at energies below the excitation threshold.

Recently experimenters have measured the differential cross sections and are interested in the spin polarization of electrons and atoms after collision. The possibility of providing intense sources of spin oriented electrons for high energy accelerators has stimulated this interest, and in this paper we calculate the elastic scattering cross sections, spin polarization and depolarization ratio.

2. Theory

The theory of spin polarization in the case of electron scattering by spin $\frac{1}{2}$ atoms has been given by Burke and Schey (1962).

Let us assume there is no correlation between the electron beam and target atoms. Then the spin polarization of the initially unpolarized electron beam scattered by fully polarized atoms and the spin polarization of atoms after the scattering of the initially completely polarized electron beam by unpolarized atoms is

$$P(\Theta) = 1 - \frac{|F^+(\Theta)+F^-(\Theta)|^2}{|F^+(\Theta)|^2+3|F^-(\Theta)|^2} \tag{1}$$

where Θ is the scattering angle. Burke and Taylor (1969) called P the exchange polarization.† Below the excitation threshold the singlet F^+ and triplet F^- scattering amplitudes may be written as

$$F^{\pm}(\Theta) = \tfrac{1}{2}(\mathrm{i}k)^{-1}\sum_L (2L+1)\{\exp(2\mathrm{i}\delta_L^{\pm})-1\}P_L(\cos\Theta) \tag{2}$$

where k is the wavenumber, L is the total angular momentum, δ is the phase shift.

† In the text Burke and Taylor call $p(\Theta) = P(\Theta)\sigma(\Theta)$ the exchange polarization but in figure 5 $P(\Theta)$ is plotted. Also in expression (12) $-$Re should be $+$Re.

Sometimes it is more convenient to use direct and exchange amplitudes which may be expressed in terms of the singlet and triplet amplitudes as follows

$$f(\Theta) = \tfrac{1}{2}\{F^{+}(\Theta)+F^{-}(\Theta)\}$$
$$g(\Theta) = \tfrac{1}{2}\{F^{+}(\Theta)-F^{-}(\Theta)\}. \tag{3}$$

The differential cross section is given by

$$\sigma(\Theta) = \tfrac{1}{4}|F^{+}(\Theta)|^2+\tfrac{3}{4}|F^{-}(\Theta)|^2$$
$$= \tfrac{1}{2}\{|f(\Theta)|^2+|g(\Theta)|^2+|f(\Theta)-g(\Theta)|^2\}. \tag{4}$$

The direct and exchange cross sections are defined as

$$\sigma_{\mathrm{d}}(\Theta) = |f(\Theta)|^2 \qquad \sigma_{\mathrm{ex}}(\Theta) = |g(\Theta)|^2. \tag{5}$$

The total exchange cross section is determined by

$$Q_{\mathrm{ex}} = \frac{\pi}{k^2}\sum_L (2L+1)\sin^2(\delta_L^{+}-\delta_L^{-}). \tag{6}$$

Employing equations (3), (4) and (5) the expression (1) for the exchange polarization may be rewritten as

$$P(\Theta) = 1-\frac{\sigma_{\mathrm{d}}(\Theta)}{\sigma(\Theta)}. \tag{7}$$

The spin polarization of the initially fully polarized electron beam scattered by unpolarized atoms and the spin polarization of atoms after the scattering of initially unpolarized electrons by completely polarized atoms is

$$N(\Theta) = 1-\frac{|F^{+}(\Theta)-F^{-}(\Theta)|^2}{|F^{+}(\Theta)|^2+3|F^{-}(\Theta)|^2} = 1-d(\Theta). \tag{8}$$

This is so-called direct polarization.

The depolarization ratio

$$d(\Theta) = \sigma_{\mathrm{ex}}(\Theta)/\sigma(\Theta) \tag{9}$$

shows to what extent the free electron or atom loses its polarization as a result of the collision. For the depolarization ratio and the exchange and direct polarization we obtain from previous equations

$$0 \leqslant d \leqslant \tfrac{4}{3} \qquad -\tfrac{1}{3} \leqslant N \leqslant 1 \qquad -\tfrac{1}{3} \leqslant P \leqslant 1 \tag{10}$$

The value $-\frac{1}{3}$ for the exchange polarization occurs, when $f = 2g$ or $F^{+} = 3F^{-}$. The direct polarization is equal to $-\frac{1}{3}$ when $g = 2f$ or $F^{+} = -3F^{-}$. (Then the depolarization ratio has the maximum possible value $\frac{4}{3}$).

3. Results and discussion

To calculate cross sections and the spin polarization phase shifts evaluated in the ground and first excited state close coupling approximation (Karule 1965) are used. These phase shifts were not published earlier and are given in table 1.

Table 1. Phase shifts

Energy (eV)	L	+	−	L	Without exchange
Lithium					
0·1	0	2·446	2·913	2	0·024
	1	0·125	1·647	3	0·006
0·2	0	2·146	2·708	2	0·066
	1	0·219	2·051	3	0·016
				4	0·007
0·4	0	1·768	2·414	2	0·132
	1	0·275	2·047	3	0·042
				4	0·018
				5	0·008
				6	0·006
0·6	0	1·515	2·198	3	0·065
	1	0·281	1·971	4	0·027
	2	0·213	0·179	5	0·015
				6	0·009
0·8	0	1·325	2·044	3	0·087
	1	0·281	1·894	4	0·039
	2	0·296	0·223	5	0·019
				6	0·012
1·0	0	1·174	1·877	3	0·108
	1	0·286	1·824	4	0·050
	2	0·387	0·261	5	0·025
				6	0·015
				7	0·014
1·2	0	1·051	1·751	3	0·131
	1	0·309	1·762	4	0·060
	2	0·493	0·293	5	0·032
				6	0·018
				7	0·014
1·4	0	0·947	1·639	3	0·153
	1	0·359	1·707	4	0·071
	2	0·623	0·320	5	0·037
				6	0·022
				7	0·014
1·6	0	0·859	1·540	3	0·176
	1	0·461	1·659	4	0·082
	2	0·790	0·343	5	0·044
				6	0·024
				7	0·016
1·8	0	0·783	1·450	3	0·202
	1	0·734	1·618	4	0·094
	2	1·038	0·363	5	0·050
				6	0·028
				7	0·020
Sodium					
0·05	0	2·649	3·066	2	0·008
	1	0·038	0·403		
0·1	0	2·421	2·935	2	0·024
	1	0·151	0·781	3	0·006
0·2	0	2·116	2·736	2	0·064
	1	0·251	1·495	3	0·015
				4	0·007
0·3	0	1·902	2·580	2	0·094
	1	0·268	1·657	3	0·030
				4	0·010
0·4	0	1·734	2·449	2	0·127
	1	0·271	1·698	3	0·040
				4	0·017
				5	0·008
				6	0·006
0·6	0	1·479	2·237	3	0·063
	1	0·272	1·687	4	0·027
	2	0·199	0·174	5	0·014
				6	0·009
0·8	0	1·289	2·066	3	0·084
	1	0·273	1·631	4	0·038
	2	0·274	0·212	5	0·019
				6	0·012
1·0	0	1·139	1·922	3	0·104
	1	0·277	1·570	4	0·048
	2	0·346	0·239	5	0·025
				6	0·014
1·2	0	1·017	1·797	3	0·124
	1	0·285	1·513	4	0·057
	2	0·425	0·285	5	0·031
				6	0·017
1·4	0	0·915	1·687	3	0·144
	1	0·300	1·462	4	0·068
	2	0·515	0·311	5	0·036
				6	0·021
				7	0·014
1·6	0	0·829	1·588	3	0·164
	1	0·333	1·417	4	0·078
	2	0·618	0·333	5	0·042
				6	0·024
				7	0·016
1·8	0	0·756	1·499	3	0·185
	1	0·404	1·375	4	0·088
	2	0·744	0·352	5	0·048
				6	0·027
				7	0·017
2·0	0	0·694	1·417	3	0·208
	1	0·575	1·337	4	0·098
	2	0·921	0·369	5	0·053
				6	0·031
				7	0·018

Table 1—(*continued*)

Energy (eV)	L	+	−	L	Without exchange	Energy (eV)	L	+	−	L	Without exchange
Potassium						*Caesium*					
0·1	0	2·400	2·953	2	0·045	0·1	0	2·391	2·942	3	0·014
	1	0·264	2·305	3	0·010		1	0·402	2·629	4	0·008
				4	0·005		2	0·090	0·052		
0·2	0	2·059	2·695	3	0·028	0·2	0	2·024	2·646	3	0·042
	1	0·333	2·189	4	0·012		1	0·503	2·368	4	0·017
	2	0·117	0·106	5	0·005		2	0·220	0·177	5	0·008
0·4	0	1·641	2·349	3	0·075	0·4	0	1·570	2·239	3	0·112
	1	0·387	1·984	4	0·032		1	0·581	2·056	4	0·046
	2	0·259	0·240	5	0·015		2	0·482	0·411	5	0·021
				6	0·011					6	0·017
0·6	0	1·363	2·098	3	0·117	0·6	0	1·268	1·951	3	0·176
	1	0·392	1·832	4	0·049		1	0·630	1·837	4	0·072
	2	0·423	0·317	5	0·026		2	0·875	0·594	5	0·038
				6	0·016					6	0·023
0·8	0	1·157	1·894	3	0·155	0·8	0	1·046	1·721	4	0·103
	1	0·403	1·701	4	0·070		1	0·711	1·667	5	0·050
	2	0·595	0·388	5	0·034		2	1·227	0·811	6	0·032
				6	0·022		3	0·222	0·253	7	0·024
				7	0·019						
1·0	0	0·996	1·726	4	0·089	1·0	0	0·872	1·529	4	0·131
	1	0·445	1·590	5	0·045		1	0·839	1·529	5	0·066
	2	0·774	0·450	6	0·026		2	1·503	1·074	6	0·038
	3	0·195	0·192	7	0·022		3	0·285	0·316	7	0·030
1·2	0	0·866	1·580	4	0·106	1·2	0	0·733	1·365	4	0·158
	1	0·531	1·491	5	0·057		1	1·015	1·411	5	0·083
	2	0·968	0·501	6	0·032		2	1·714	1·329	6	0·047
	3	0·230	0·238	7	0·023		3	0·353	0·421	7	0·033
1·4	0	0·760	1·452	4	0·126	1·4	0	0·620	1·221	4	0·188
	1	0·681	1·402	5	0·066		1	1·308	1·311	5	0·094
	2	1·179	0·547	6	0·038		2	1·890	1·570	6	0·049
	3	0·266	0·285	7	0·025		3	0·443	0·656	7	0·040
1·6	0	0·673	1·338	4	0·145						
	1	1·047	1·325	5	0·080						
	2	1·449	0·587	6	0·037						
	3	0·303	0·340	7	0·027						

+ denotes the symmetric and − the antisymmetric case.

For lithium and sodium phase shifts and total exchange cross sections (table 2) are in good agreement with those of Burke and Taylor (1969) and Norcross (1971).

The differential cross sections are given in table 3. For lithium, sodium and potassium the differential cross sections have one minimum. The width of minimum increases with energy. For caesium at energies of 1 eV and above the differential cross section has two minima.

The depolarization ratios are listed in table 4. The percent exchange polarization as a function of the scattering angle and energy is plotted in the energy range from 0·1 eV to the excitation threshold in figure 1.

Table 2. Total exchange cross sections

Energy (eV)	Li	Na	K	Cs
0·0	86·7	103	237	452
0·05		149		
0·1	435	175	362	295
0·2	210	206	212	211
0·3		149		
0·4	110	115	116	115
0·6	76·2	77·2	78·4	77·2
0·8	58·7	57·4	58·6	54·7
1·0	47·5	45·3	46·8	33·4
1·2	40·5	36·9	39·2	17·4
1·4	36·0	31·3	33·6	11·0
1·6	33·4	27·3	29·7	
1·8	31·2	24·4		
2·0		22·1		

Table 3. Differential cross sections (in $a_0^2 = 2{\cdot}8 \times 10^{-17}\ \mathrm{cm}^2$)

$\theta°$	Energy (eV)											
	0·1	0·2	0·3	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
Lithium												
0	957	418		265	257	272	313	343	375	413	463	
10	929	409		258	243	251	279	301	326	355	397	
20	850	383		239	213	206	210	216	225	238	261	
30	728	342		217	183	165	155	148	144	144	151	
40	578	290		191	157	134	120	107	97·9	91·2	90·2	
50	418	230		158	129	108	91·6	79·0	68·6	60·3	55·3	
60	267	167		121	98·1	80·8	66·6	55·6	46·5	39·1	33·3	
70	142	107		83·7	68·2	55·3	45·7	37·0	30·1	24·7	20·5	
80	57·9	59·3		52·3	42·8	34·2	28·3	22·4	17·9	14·9	13·2	
90	24·4	29·7		29·1	23·6	18·2	13·8	10·5	8·3	7·3	7·9	
100	45·3	22·2		15·7	11·2	7·7	4·4	2·8	2·0	2·2	4·1	
110	118	37·1		13·8	7·1	3·8	1·7	0·6	0·2	0·6	2·4	
120	233	71·4		23·5	11·7	7·0	4·3	3·0	2·3	2·0	2·6	
130	377	120		42·1	23·0	15·5	11·0	8·9	7·5	6·4	5·4	
140	531	175		65·4	37·8	26·7	21·2	17·9	15·6	13·8	11·3	
150	677	231		89·7	53·6	38·8	32·9	28·2	25·1	22·9	19·5	
160	796	278		112	68·1	50·7	41·7	36·1	32·9	30·5	26·8	
170	874	309		128	79·0	60·0	45·5	39·7	37·0	34·7	31·1	
180	901	321		134	83·2	63·6	46·4	40·6	38·1	35·9	32·4	
Sodium												
0	478	541	406	351	313	313	314	344	379	400	423	453
10	459	524	393	336	294	289	285	308	330	344	361	385
20	407	475	358	300	251	234	221	228	227	229	234	245
30	332	404	308	256	205	180	161	154	143	136	132	133
40	248	320	250	211	166	140	119	106	94·1	84·3	76·7	72·6
50	168	235	192	165	130	107	89·4	75·8	64·5	55·3	47·7	42·2
60	99·8	156	137	119	95·2	77·6	63·9	52·5	43·1	35·8	29·8	24·9
70	50·2	91·8	88·0	78·6	64·1	51·9	42·2	33·8	27·6	22·5	18·5	15·2
80	23·3	47·7	50·5	47·4	39·7	31·8	25·3	20·0	16·7	13·6	11·4	10·0
90	22·3	28·4	28·3	27·7	22·8	17·7	13·6	10·7	8·4	6·8	6·1	6·3

Table 3—(*continued*)

θ°	Energy (eV)										
	0·1	0·2	0·3	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
Sodium—continued												
100	48·3	35·8	23·9	19·9	13·5	9·3	6·5	4·7	2·9	2·2	2·2	3·2
110	99·3	68·4	37·2	24·3	12·2	6·8	3·9	2·3	1·1	0·6	0·6	1·3
120	169	122	65·3	40·2	18·9	10·4	6·2	3·8	2·5	1·6	1·1	1·1
130	249	188	104	64·7	31·8	18·8	12·2	8·5	6·3	4·8	3·7	2·7
140	327	259	146	93·3	48·0	29·7	20·0	14·9	11·8	9·8	8·1	6·4
150	395	325	188	122	64·4	41·0	28·2	21·7	18·3	15·8	13·8	11·7
160	447	379	222	145	78·7	51·1	35·6	28·2	23·7	20·9	18·9	16·9
170	478	414	245	161	88·7	58·6	41·1	33·2	26·9	23·9	22·1	20·5
180	488	426	252	167	92·3	61·4	43·2	35·2	27·9	24·9	23·1	21·8
Potassium												
0	505	359		421	532	683	784	870	939	988		
10	495	352		391	480	591	670	736	790	829		
20	464	332		327	366	405	438	465	486	505		
30	415	303		267	262	258	255	251	247	249		
40	349	267		222	196	174	155	138	124	117		
50	272	222		182	149	121	98·4	79·6	64·3	54·2		
60	190	168		139	109	82·3	62·2	46·3	33·7	24·4		
70	114	114		98·8	74·7	56·0	40·3	28·8	20·5	13·8		
80	57·1	68·2		65·2	48·0	36·7	26·2	19·5	15·4	12·2		
90	27·1	37·4		39·1	28·1	19·3	13·9	11·6	11·1	11·8		
100	29·4	25·4		21·4	13·9	6·9	4·9	5·1	6·7	10·3		
110	64·0	32·9		15·4	7·5	3·0	1·8	2·0	3·6	7·4		
120	126	58·7		23·0	10·8	5·8	3·3	2·1	2·1	3·9		
130	208	99·2		41·1	22·1	13·1	8·5	5·6	3·5	2·5		
140	300	148		64·7	37·0	25·0	18·2	13·2	8·9	4·9		
150	390	198		90·2	53·2	40·0	30·8	23·8	17·7	10·5		
160	467	240		115	69·4	51·6	40·6	32·7	26·3	17·4		
170	518	267		135	82·6	56·5	44·7	37·6	32·1	23·7		
180	536	276		143	87·9	57·4	45·6	39·1	34·3	26·6		
Caesium												
0	254	347		762	1169	1540	1696	1737	1830			
10	250	333		686	1037	1329	1455	1480	1546			
20	237	302		520	741	887	954	950	964			
30	218	268		369	464	512	531	508	483			
40	192	239		272	285	282	270	242	204			
50	159	209		208	180	147	119	91·2	59·9			
60	121	172		157	114	72·8	42·1	21·1	7·4			
70	82·8	128		115	73·3	43·3	18·9	7·3	8·0			
80	51·1	86·8		82·5	51·3	35·1	21·3	17·8	23·3			
90	32·4	54·2		54·8	36·8	27·8	26·2	29·4	35·1			
100	30·1	34·5		30·0	21·9	18·7	25·4	32·6	38·7			
110	43·9	29·8		15·1	9·9	11·2	18·2	24·2	29·1			
120	71·1	41·6		16·3	8·2	6·6	7·9	9·5	11·9			
130	108	70·0		31·3	17·5	8·2	3·2	1·4	2·5			
140	151	111		54·5	34·4	28·7	10·4	5·9	5·9			
150	194	155		83·5	57·2	42·9	28·2	21·8	21·2			
160	232	192		118	84·0	64·5	49·3	45·8	52·1			
170	259	216		149	108	77·6	67·0	71·5	93·0			
180	268	225		162	118	81·8	74·4	83·6	114			

At zero energy the scattering is isotropic, therefore the polarization and depolarization ratios are not dependent on the scattering angle (table 5). But the energy range of the isotropic scattering for alkali atoms is negligible, since at energies less than 0·1 eV several partial waves contributed to cross sections.

From figure 1 it is evident, that the exchange polarization for all alkali atoms has a maximum at scattering angles 115°–150°. At some incident electron energies the maximum value of the exchange polarization is 95–100%. The other lower maximum is located at the scattering angles 65°–80°. At energies close to the excitation threshold

Table 4. Depolarization ratios $d(\theta) \times 10^2$

$\theta°$	Energy (eV)											
	0·1	0·2	0·3	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
Lithium												
0	24	25		26	23	18	13	10	7	5	3	
30	23	21		23	24	23	21	18	14	10	6	
40	21	19		21	22	22	22	20	18	14	8	
50	19	15		18	19	20	21	21	20	18	12	
60	16	11		14	16	18	19	21	23	25	24	
70	10	6		10	12	14	16	19	25	34	44	
80	3	2		7	8	9	11	16	26	44	71	
90	28	16		11	7	6	5	10	26	58	99	
95	58	42		21	12	7	3	6	26	68	112	
100	67	76		43	27	16	5	1	24	82	119	
105	64	96		77	59	45	32	9	21	95	109	
110	60	99		106	101	97	101	97	71	65	77	
113	58	97		113	117	119	124	121	83	38	52	
115	56	94		114	122	124	126	116	80	34	37	
120	53	88		109	117	116	112	98	74	43	18	
130	49	77		92	94	89	86	78	71	64	44	
140	47	70		81	79	75	70	68	69	72	70	
150	45	65		73	71	67	61	63	68	77	84	
160	45	62		68	65	61	60	63	70	82	95	
180	44	60		64	60	56	63	67	76	91	108	
Sodium												
0	21	16	17	17	16	13	11	8	6	4	2	1
30	22	15	16	17	18	18	17	14	12	9	6	3
40	23	14	14	15	17	18	18	17	16	14	11	6
50	24	11	12	13	16	17	18	19	19	19	17	12
60	26	8	9	10	14	16	17	19	22	24	26	26
70	30	3	5	7	10	13	15	19	23	29	38	48
80	36	0	3	5	8	9	12	16	22	33	49	72
85	39	5	6	7	7	8	9	13	10	33	54	82
90	34	20	16	13	10	7	7	10	17	33	59	91
100	29	55	56	47	34	22	12	6	8	27	66	103
109	27	60	75	77	76	68	57	41	25	2	31	77
114	26	59	75	82	89	90	87	79	66	34	0	31
120	26	56	71	80	91	95	97	95	85	69	38	3
130	26	52	65	73	82	86	88	88	88	86	81	61
140	26	50	61	67	74	78	80	83	86	90	94	94
150	26	48	58	63	69	72	76	80	84	91	99	107
160	26	47	56	61	65	69	73	78	85	94	104	114
180	26	47	55	59	63	65	69	74	88	99	111	121

Table 4—(*continued*)

$\theta°$	Energy (eV) 0·1	0·2	0·3	0·4	0·6	0·8	1·0	1·2	1·4	1·6	1·8	2·0
Potassium												
0	32	32		19	12	6	3	1	0	1		
30	28	27		23	19	13	8	4	1	1		
40	24	23		22	20	16	12	7	3	0		
50	19	19		19	19	19	17	14	10	2		
60	13	14		16	17	19	23	26	28	19		
70	6	9		12	14	18	28	42	58	68		
80	2	5		8	9	14	29	53	81	106		
90	35	16		8	4	9	28	62	93	114		
95	79	35		13	4	5	27	65	96	110		
100	110	65		27	9	2	21	65	93	102		
105	114	93		53	27	7	8	53	81	91		
110	107	106		84	63	37	1	23	57	75		
115	99	107		101	94	72	29	0	23	56		
120	91	101		102	100	87	61	22	1	32		
125	85	94		96	94	90	80	59	25	9		
130	80	88		88	87	89	88	83	68	15		
140	74	78		77	77	81	88	98	108	90		
150	69	71		69	70	74	85	101	117	121		
160	66	67		63	65	74	89	108	124	131		
170	64	65		58	61	78	96	116	129	131		
180	64	65		57	59	80	100	120	131	128		
Caesium												
0	68	44		13	4	0	0	1	1			
30	55	41		20	9	2	1	1	1			
50	34	27		21	16	11	7	4	0			
60	23	19		18	19	25	27	25	14			
65	17	16		16	21	35	49	65	43			
70	12	12		13	21	42	69	89	26			
75	9	9		10	21	45	69	59	15			
80	9	7		7	18	43	57	37	10			
90	35	9		3	11	36	35	18	6			
100	97	37		7	3	23	19	10	5			
105	118	65		20	0	14	13	7	6			
110	127	94		48	4	4	7	5	8			
115	127	112		82	25	0	2	3	13			
120	124	116		97	55	13	0	3	23			
130	113	101		86	77	84	81	75	103			
132	111	98		83	77	91	100	112	111			
135	108	92		78	77	93	104	100	83			
140	103	85		72	77	89	87	58	32			
150	95	74		61	72	78	64	32	6			
160	89	68		51	66	75	56	23	2			
180	84	65		42	58	78	50	17	1			

the second maximum of the exchange polarization for potassium is 94 %, for caesium 96 %, but for lithium and sodium only 83 %. Between both maxima there is a region, where the exchange polarization has a minimum. At some energies polarization in this region goes through zero and has the opposite sign. For sodium at 0·1, 2 eV the respective

Table 5. The differential cross section, exchange polarization and depolarization ratio at zero energy

	Li	Na	K	Cs
$\sigma\ (a_0^2)$	27·4	30·7	168	484
P (%)	96·3	97·7	68·7	55·6
d	0·79	0·84	0·35	0·23

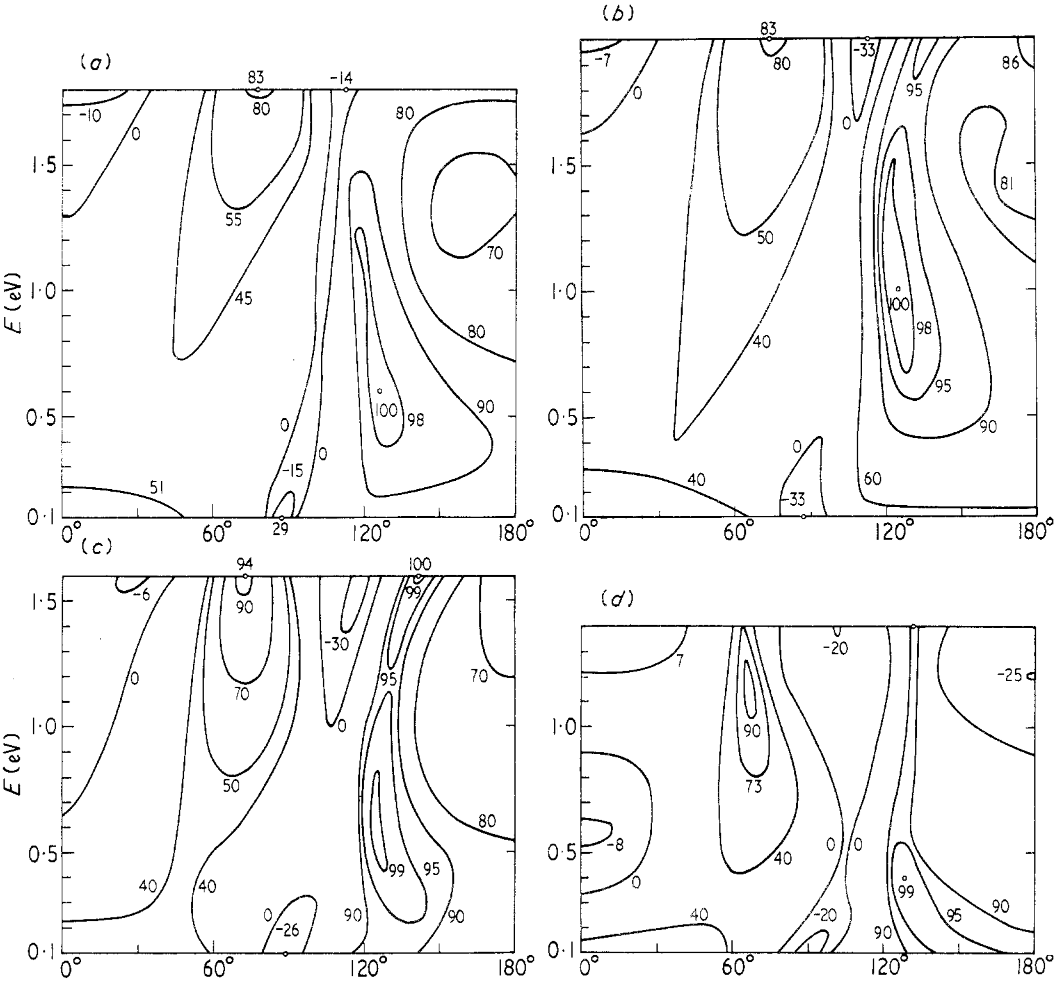

Figure 1. The percent exchange polarization for (*a*) lithium, (*b*) sodium, (*c*) potassium, (*d*) caesium, as a function of the electron energy and scattering angle.

scattering angles 88°, 114°, for potassium at energy 1·6 eV and an angle of 119° the exchange polarization is close to the theoretical limit $-\frac{1}{3}$.

For lithium, sodium and potassium the exchange polarization for the backward scattering is greater than for the forward scattering, since at $\Theta = \pi$ the exchange cross section is greater than the direct one, but at $\Theta = 0$ vice versa. Only for caesium in both cases the direct cross section is greater than the exchange one.

If we compare the behaviour of the differential cross section and the exchange polarization as functions of the scattering angle, then we see that the maximum of the exchange polarization is dislocated close to the minimum of the differential cross section. It is because the minima of the direct and exchange cross sections are placed close to the minimum of $\sigma(\Theta)$, but do not coincide with it.

The exchange cross section is the first to go through the minimum (if $\sigma_{ex} = 0$, then $P = d = 0$). If all the scattering is due to the exchange then $\sigma_d = 0$ and scattered electrons are completely polarized. The closer to one another the minima of the exchange and direct cross sections the more rapidly the spin polarization changes in this region. If $\sigma(\Theta)$ has a wide minimum as is usual at energies close to the excitation threshold, then σ_d and σ_{ex} have two minima and correspondingly the exchange polarization has two maxima displaced on both sides of the minimum of the differential cross section.

We have no experimental data on the electron spin polarization to compare.

Collins *et al* (1971), Gehenn and Wilmers (1971) and Slevin *et al* (1972) measured the differential cross sections for potassium. The agreement between their experimental data and our calculation is satisfactory. Collins *et al* (1971) also measured the depolarization ratio. In figure 2 we give the depolarization ratio dependence on energy for backward scattering. It is evident that the theoretical curve is in good agreement with the experimental data.

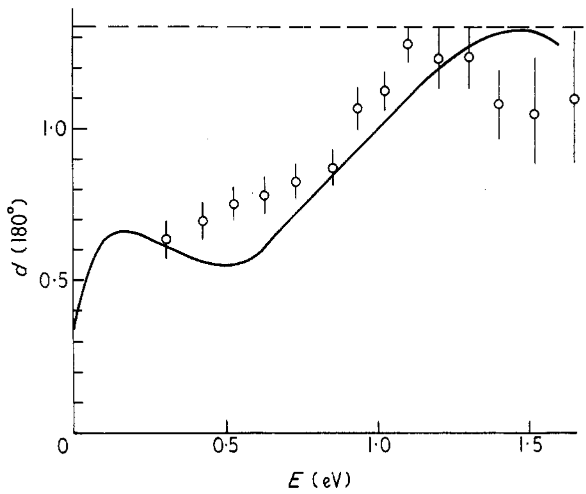

Figure 2. The depolarization ratio as a function of energy for backward scattering for potassium. The solid curve is theoretical and the circles are the results of Collins *et al* (1971).

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