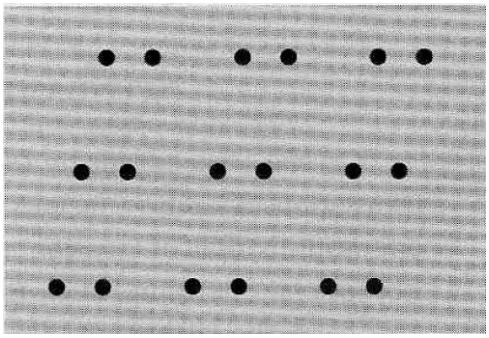
NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 580 – Solid State Physics Fall 2024

Problem Set #1

Problem Set Due: Thurs., Sept. 5, 2024
Read Kittel: Chapter 1, powerpoint: *Geometry of Crystals*



1. The points in the figure above are identical atoms. Sketch on the figure

(a) a set of lattice points

(b) a choice of primitive axes

(c) a primitive cell based on your choice of primitive axes

(d) the basis of atoms associated with a lattice point

(e) the Wigner-Seitz primitive cell

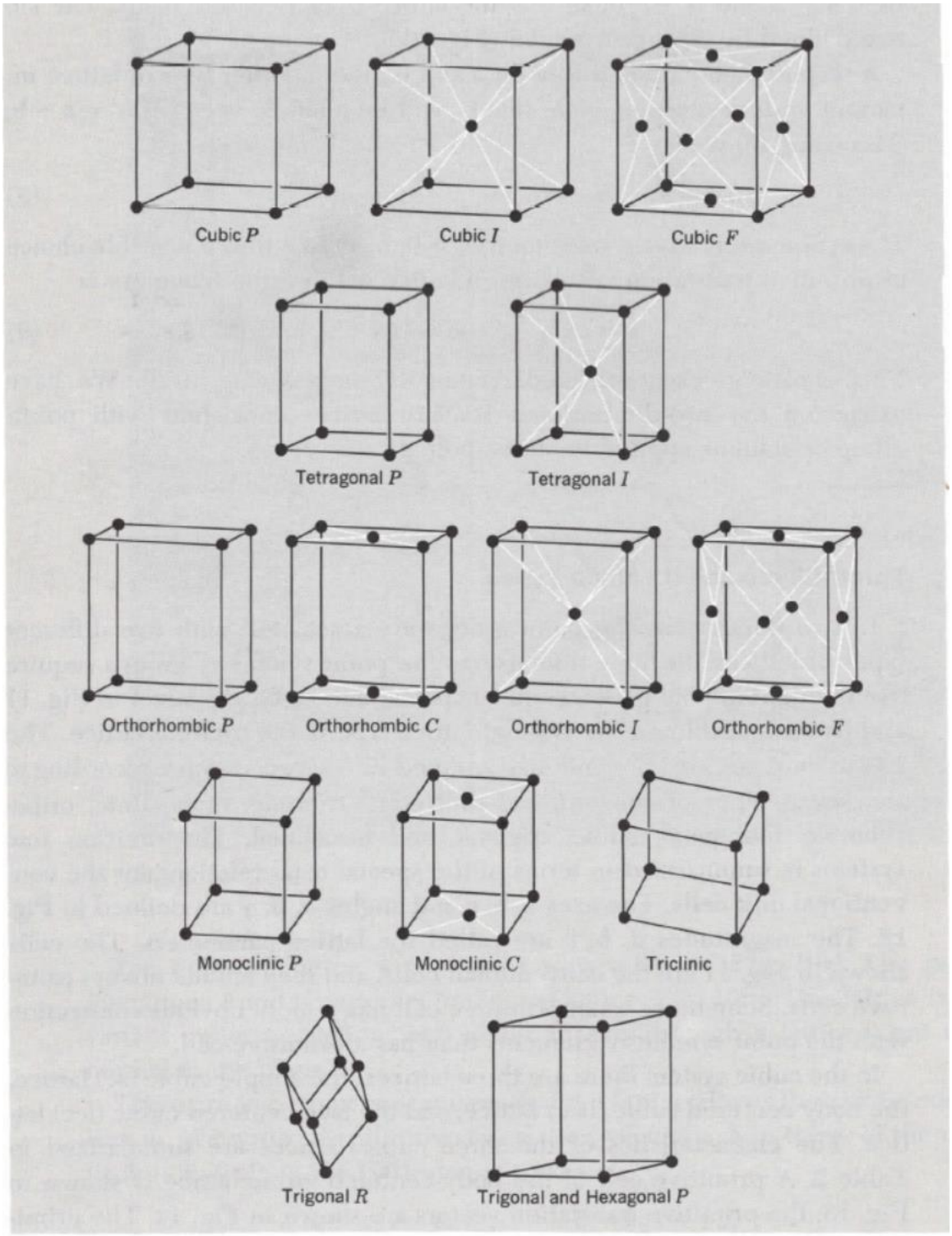


Figure 11 The 14 Bravais or space lattices. The cells shown are the conventional cells, which are not always the primitive cells.

2. Figure 11 from Kittel (5th edition) on page 14.

(a) Describe the difference between type P, I, and F crystal structures.

(b) Which structure has a rhombohedral shape and what type crystal structure does it have?

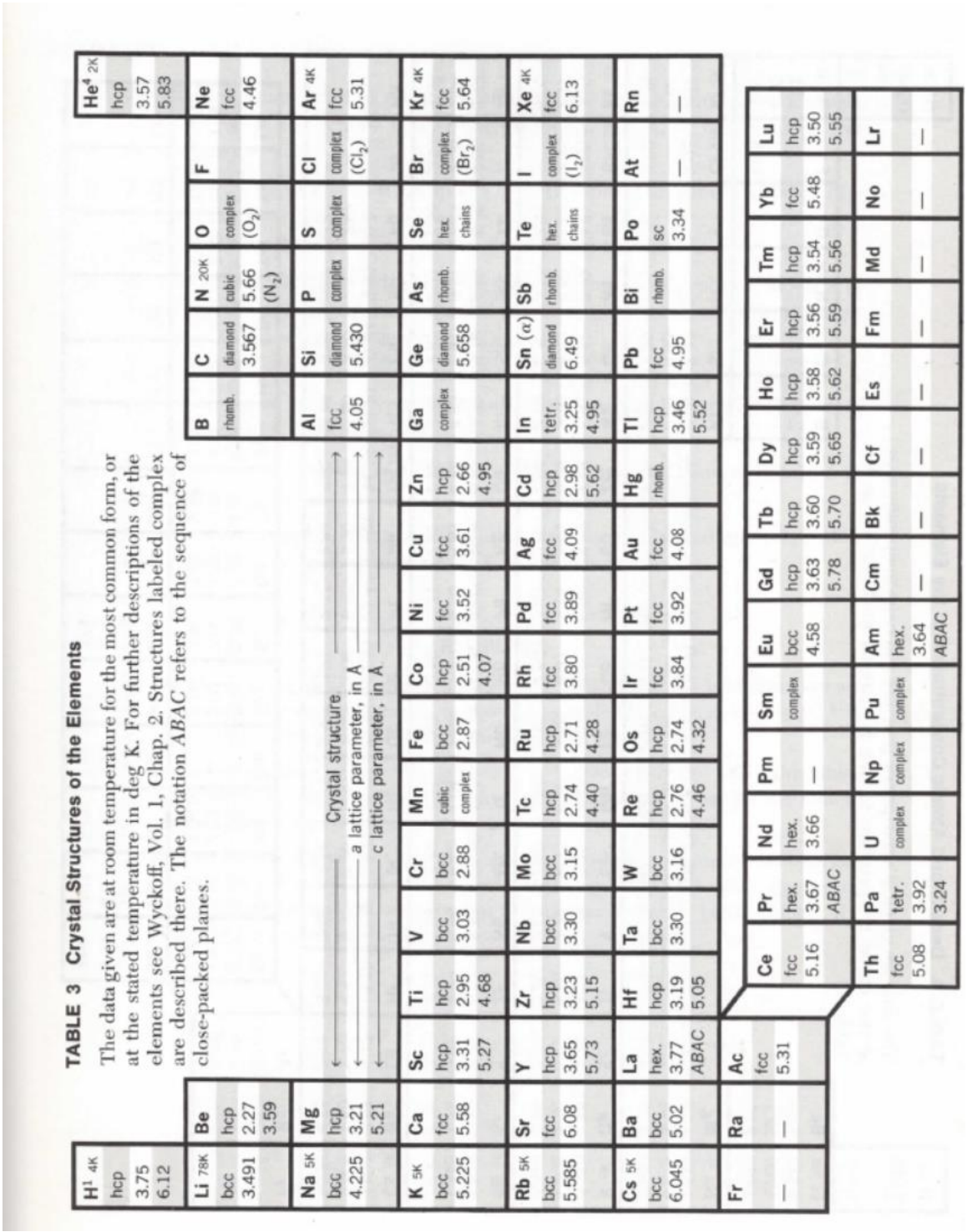


TABLE 3 Crystal Structures of the Elements

The data given are at room temperature for the most common form, or at the stated temperature in deg K. For further descriptions of the elements see Wyckoff, Vol. 1, Chap. 2. Structures labeled complex are described there. The notation *ABAC* refers to the sequence of close-packed planes.

H^{1} 4K																													He^{4} 2K
hcp													B	C	N 20K	O	F											hcp
3.75													rhomb.	diamond	cubic	complex													3.57
6.12														3.567	5.66	(O_2)													5.83
Li 78K	Be														(N_2)														
bcc	hcp												Al	Si	P	S	Cl												Ne
3.491	2.27												fcc	diamond	complex	complex	complex												fcc
	3.59												4.05	5.430			(Cl_2)												4.46
Na 5K	Mg																												
bcc	hcp	← Crystal structure →																											Ar 4K
4.225	3.21	← *a* lattice parameter, in Å →																											fcc
	5.21	← *c* lattice parameter, in Å →																											5.31
K 5K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr 4K												
bcc	fcc	hcp	hcp	bcc	bcc	cubic	bcc	hcp	fcc	fcc	hcp	complex	diamond	rhomb.	hex.	complex	fcc												
5.225	5.58	3.31	2.95	3.03	2.88	complex	2.87	2.51	3.52	3.61	2.66		5.658		chains	(Br_2)	5.64												
		5.27	4.68					4.07			4.95																		
Rb 5K	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn (*a*)	Sb	Te	I	Xe 4K												
bcc	fcc	hcp	hcp	bcc	bcc	hcp	hcp	fcc	fcc	fcc	hcp	tetr.	diamond	rhomb.	hex.	complex	fcc												
5.585	6.08	3.65	3.23	3.30	3.15	2.74	2.71	3.80	3.89	4.09	2.98	3.25	6.49		chains	(I_2)	6.13												
		5.73	5.15			4.40	4.28				5.62	4.95																	
Cs 5K	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn												
bcc	bcc	hex.	hcp	bcc	bcc	hcp	hcp	fcc	fcc	fcc	rhomb.	hcp	fcc	rhomb.	sc														
6.045	5.02	3.77	3.19	3.30	3.16	2.76	2.74	3.84	3.92	4.08		3.46	4.95		3.34	—	—												
		ABAC	5.05			4.46	4.32					5.52																	
Fr	Ra	Ac																											
—	—	fcc																											
		5.31																											

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
fcc	hex.	hex.		complex	bcc	hcp	hcp	hcp	hcp	hcp	hcp	fcc	hcp			
5.16	3.67	3.66	—		4.58	3.63	3.60	3.59	3.58	3.56	3.54	5.48	3.50			
	ABAC					5.78	5.70	5.65	5.62	5.59	5.56		5.55			
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			
fcc	tetr.	complex	complex	complex	hex.	—	—	—	—	—	—	—	—			
5.08	3.92				3.64											
	3.24				*ABAC*											

(c) Go to the Web Elements website: https://www.webelements.com/ and fill in the blanks for the elements Ra and F (click on the crystal structure tab). That is, give their space group, structure, and unit cell lattice parameters (in angstroms) and angles. Which one of the structures in Figure 11 above do they belong to?

(d) Why does Kittle label some elements as complex?

(e) Go to the Materials Project website and login: https://next-gen.materialsproject.org/ and find all the crystal structures that F can form into. For example, it can form in the simple cubic primitive (P) structure along with other structures. Notice that the Materials Project does not provide crystal structures for several elements (like Ra).

3. Download Vesta (https://jp-minerals.org/vesta/en/) and make a model of the unit cell for Po (sc), Fe (bcc), and Cu (fcc) shown in slide 34 of the "Geometry of Crystals" powerpoint slide (the powerpoints are on Blackboard in the "Content" section). Bring you laptop to class on Tues to show your work on the overhead projector.

4. Slide 29 of the "Geometry of Crystals" powerpoint shows that there can be no face-centered tetragonal lattice. Explain why (do a Google search and show a nice geometrical figure illustrating why).