Procedure

(b)

1. Place about 1 cm of each solid, packed with a stirring rod, into a clean, dry test tube.
2. Tie the end of about 15–20 cm of thread to the top of each test tube.
3. Set up the lab stand with a horizontal bar.
4. Attach the other end of the threads to the horizontal bar for each test tube. (Tie all four test tubes to the bar if possible, or one at a time.)
5. Wait until the test tube is completely at rest and then bring the end of a strong magnet about 1 cm from the solid in the test tube.
6. Observe any deflection of the test tube, testing each solid several times.
7. Dispose of the solids or return the solids (as directed by your teacher).

Evidence

(c)

Paramagnetism of Metal Salts	
Substance	**Effect of magnet**
$CaSO_{4(s)}$	no noticeable effect
$ZnSO_4{\cdot}7H_2O_{(s)}$	no noticeable effect
$CuSO_4{\cdot}5H_2O_{(s)}$	a very slight attraction
$MnSO_4{\cdot}H_2O_{(s)}$	clearly attracted

Analysis

(d) Based on the evidence, manganese(II) ions are obviously paramagnetic and copper(II) ions are likely weakly paramagnetic.

Evaluation

(e) The experimental design should control the amount of the substances used and be more specific about the testing with the magnet, which seems a little vague. Perhaps the metal ions should be tested in solution form.

(f) More substances should be tested and a much stronger magnet should be available. The procedure should include testing the aqueous solution of each substance. Testing with a magnet should be done inside a box so that air currents are not a factor.

(g) The evidence for the manganese(II) compound appears quite certain but the others are less certain. Because the observations were not very precise, it is possible that some substances that had no effect might be weakly affected. Some sources of error or uncertainty are the qualitative judgment of any effect, possible air currents, quantity of the substances used, and the strength of the magnet.

LAB EXERCISE 3.6.1 QUANTITATIVE PARAMAGNETISM

(Page 215)

Prediction/Hypothesis

(a) Based on the hypothesis that unpaired electrons of atoms or ions in a substance are responsible for the paramagnetism of a substance, the greater the number of unpaired electrons per atom, the greater the strength of the paramagnetism.

Experimental Design

(b) The independent variable is the metal ion in the ionic compound tested. The dependent variable is the apparent change in mass as registered on the balance. Some controlled variables are the distance between the test tube and the magnet and the mass of the compound used.

Analysis

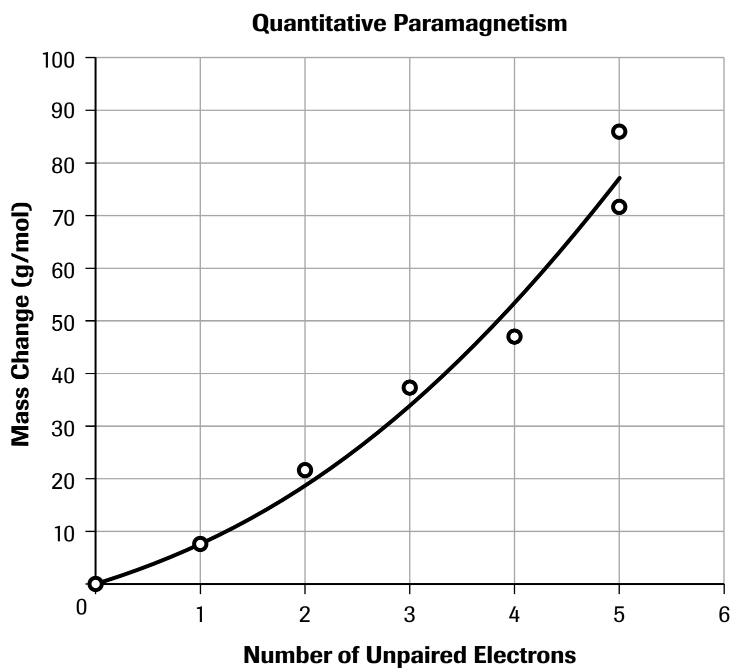
(c) A zero mass reading indicates that the substance in the test tube is not paramagnetic because it does not affect the magnet. A negative mass reading on the balance indicates that a paramagnetic substance is attracting the magnet, lifting it slightly from the balance pan.

(d) The greater the change in mass, the stronger the paramagnetism of the substance.

(e)

Quantitative Paramagnetism			
Metal ion	**Electron configuration**	**Number of unpaired electrons**	**Mass decrease per mole (g/mol)**
Ca^{2+}	[Ar]	0	0
Al^{3+}	[Ne]	0	0
Cu^{+}	$[Ar]3d^{10}$	0	0
Cu^{2+}	$[Ar]3d^{9}$	1	7
Ni^{2+}	$[Ar]3d^{8}$	2	21
Co^{2+}	$[Ar]3d^{7}$	3	37
Fe^{2+}	$[Ar]3d^{6}$	4	47
Mn^{2+}	$[Ar]3d^{5}$	5	71
Fe^{3+}	$[Ar]3d^{5}$	5	86

(f)



(g) According to the evidence collected and the graph, as the number of unpaired electrons in an ion increases, the strength of the paramagnetism increases.

Evaluation

(h) There are no obvious flaws in the design of this experiment. It may be better to control the anion present with the metal ion instead of using some chlorides and sulfates. Another improvement might be to specify more precisely the distance when the mass reading is taken. Instead of “just before” contact, a small but specific distance could be used.

(i) Many more samples repeating the same number of unpaired electrons should be tested. This would make the pattern on the graph and a specific relationship more certain.
(j) I am relatively confident in the answer because the trend on the graph seems clear.
(k) The prediction was verified because the experimental answer agrees in principle with the predicted answer.
(l) The hypothesis that the number of unpaired electrons determines the strength of the paramagnetism appears to be acceptable. The relationship is not a simple, direct one but the strength of the paramagnetism clearly increases with an increasing number of unpaired electrons per ion in the sample.

ACTIVITY 3.7.1 MODELLING STANDING ELECTRON WAVES

(Page 216)

(a) Nodes are points along the wire that do not move, while antinodes are regions along the wire that move back and forth more than anywhere else. The antinodes appear like a blur because the wire is moving very quickly back and forth.
(b) Only certain frequencies produce standing wave patterns. The patterns can form for only specific numbers of wavelengths "contained" around the wire.
(c) The number of antinodes ranges from as few as one, to as many as about twelve (depending on the size of the loop).
(d) The wave mechanics model of the atom is thought to be similar, in that electrons act like standing waves within an atom, with only certain allowable vibration energies based on electron wavelength. Some limitations of this comparison are that this activity is restricted to very simple finite patterns restricted to a circular path, whereas electron "standing waves" are three-dimensional probability structures, and sometimes very complex in nature.

ACTIVITY 3.7.2 SIMULATION OF ELECTRON ORBITALS

(Page 217)

(a) Quantum mechanics theory describes a region in space (an orbital) where an electron is likely to be found at many instances of time. The Bohr theory shows an electron as a tiny particle in a specific orbit or path.
(b) The 1*s* orbital shows a probability density that is circular (in 2-D) and decreases in density from the centre. The 2*s* orbital also has a circular probability density but it is not uniform. There is a high-density region near the centre, then a zero density shell, and then an outer high-density shell.
(c) A 2*s* orbital is much larger, and has a much higher energy than a 1*s* orbital.
(d) The 2*s* orbital has a circular electron probability density, whereas the 2*p* orbital has two lobes (∞). The $2p_x$ and $2p_y$ are identical in distribution but oriented at right angles to each other.
(e) The $2p_z$ orbital is missing. This orbital is identical in shape to the $2p_x$ and $2p_y$ orbitals except for orientation. It is oriented with its long axis at 90° to the other two *p* orbitals—into and out of the plane of the screen.
(f) With 6 electrons, the atom represented would be carbon, C.
(g) The combined electron probability distribution would be spherical.
(h)