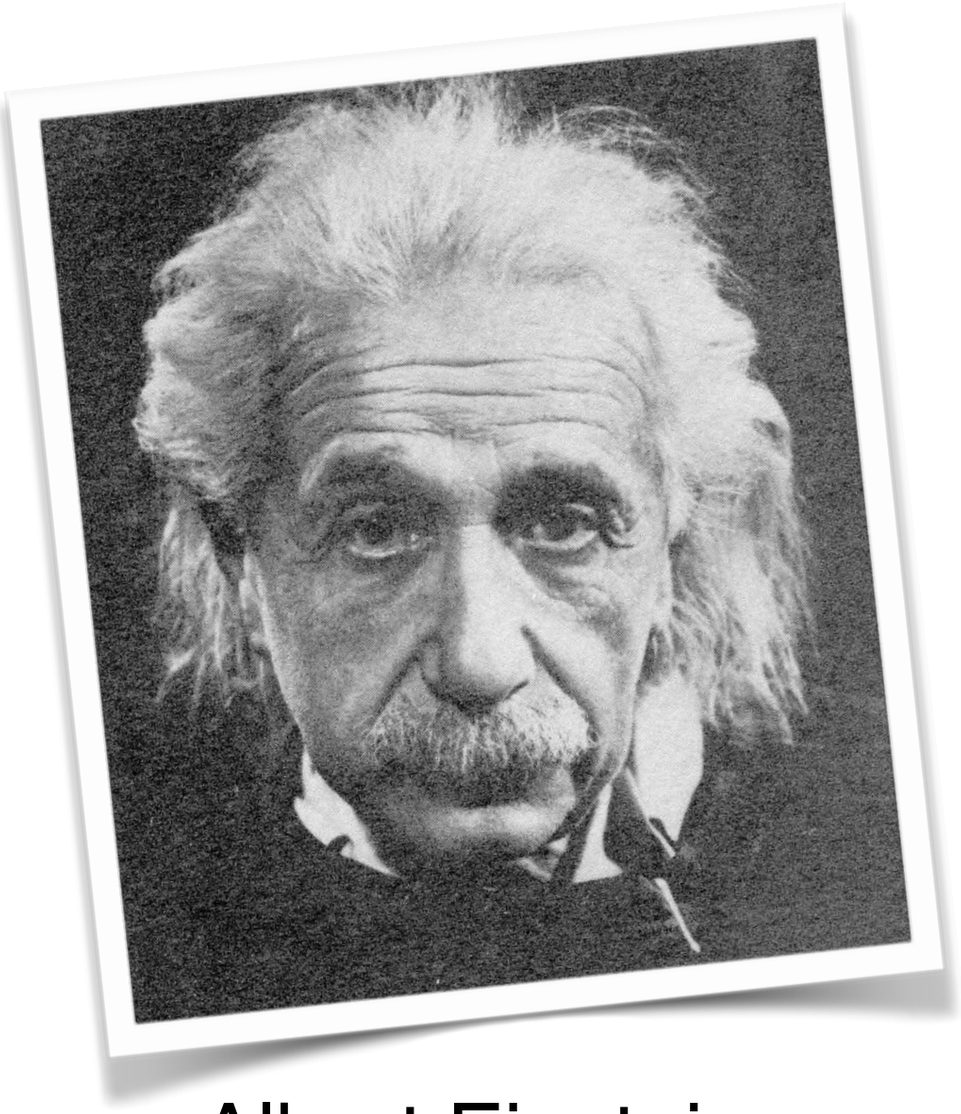
CHEM 100
Principles Of Chemistry

Chapter 1 - Reading, Writing & Doing Science

1.1 The Language Of Science

- Specific words in science have precise meanings which may be different than in everyday use
  - We must use the correct words, know their meaning, abbreviations or symbols
- Science describes **qualitative** phenomena and concepts
- Science uses mathematics and equations to describe **quantitative** relationships

$$E = m \cdot c^2$$



Albert Einstein
1879-1955

Ideas In Science

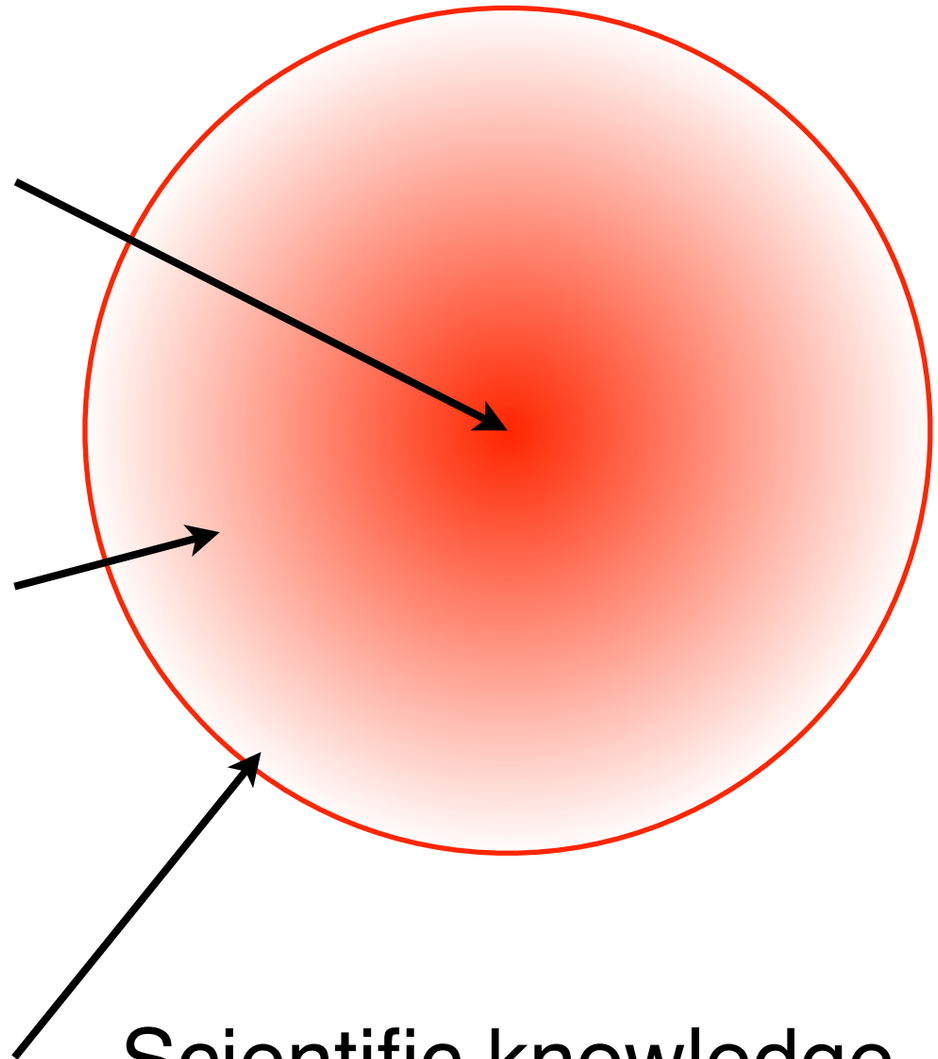
- Scientists observe and are curious
  - Scientists are detectives; they look for clues and use them to build

Don’t guess my dear Watson… observe and then deduce!

- Science expands gradually
  - New ideas are usually based on older ideas
- All ideas are continuously tested by experiments
  - Ideas passing the tests are added to knowledge
  - Ideas failing the tests are discarded or modified

The Ideas Of Science

- **Core ideas** are well established, accepted by most and infrequently revised
- **Frontier ideas** are new ideas being tested, accepted by many and undergoing frequent revisions
- **Fringe ideas** or pseudoscience are highly speculative, accepted by



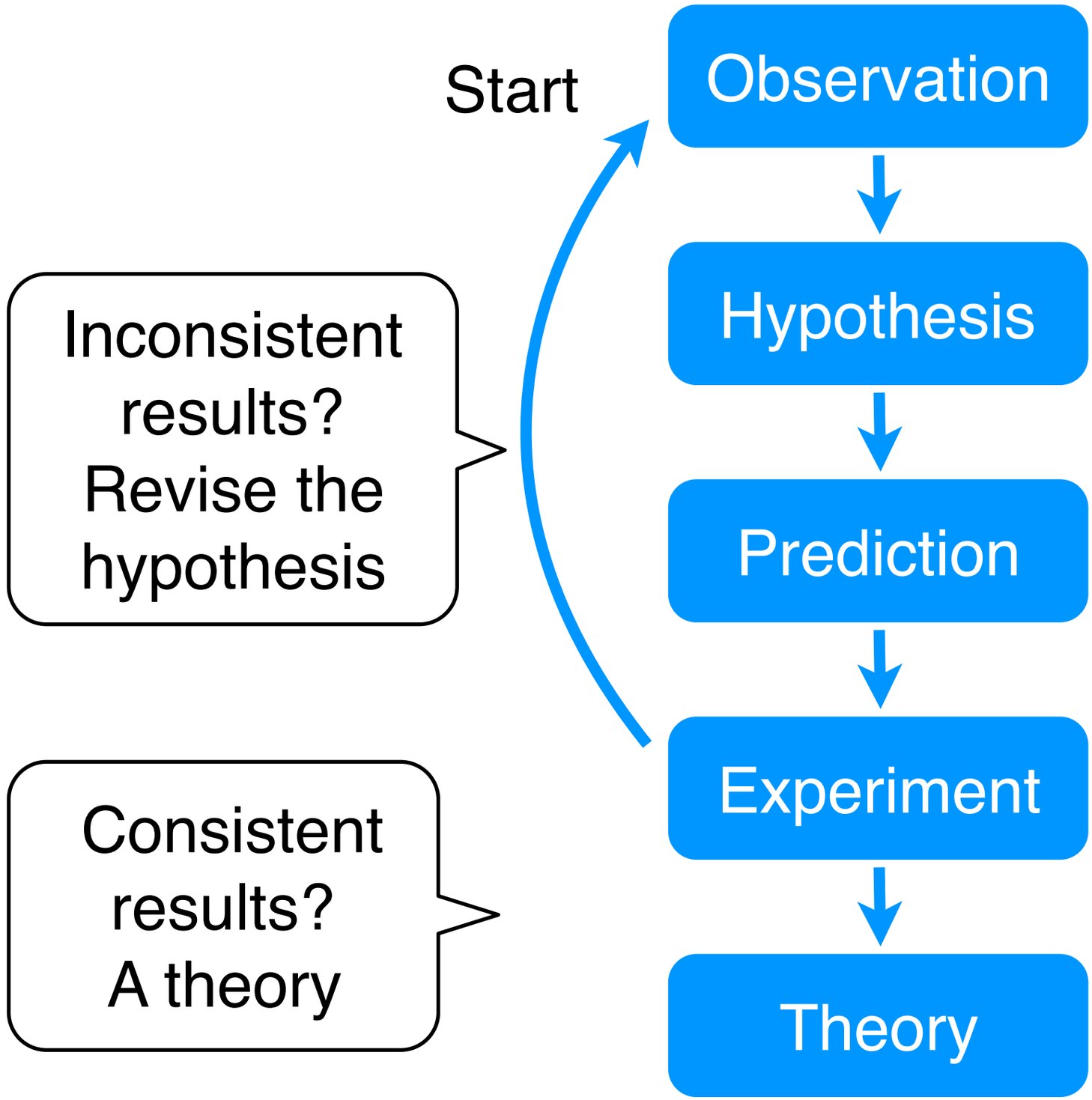
Rarely become frontier or core ideas

Test Yourself: Core, Frontier or Fringe Idea?

1. The earth orbits the sun due to gravity
   - A core idea
2. Ingredients for life on earth were brought by comets
   - A frontier idea
3. Human beings exist on Earth because they were placed here by alien creatures
   - A fringe idea
4. Global warming occurs because of human activity
   - A frontier idea
5. Life developed on earth because of evolution
   - A core idea

1.2 Doing Science

- Most theories develop through a systematic process called the **scientific method**
- **Occam's razor** states that the simplest hypothesis is



Example of The Scientific Method

- My car won't start (**observation**)
- The car is out of gas (**hypothesis**)
- If I add gasoline, the car will start (**prediction**)
- I add gasoline (**experiment**)
  - My car started! (**observation**)
  - Gas is required to start a car (**theory**)

Consistent results? A theory

Try these observations:

- Bubbles appear when water boils
- Ice is slippery

Example of The Scientific Method

- The sky is blue (**observation**)
- The sky is painted blue (**hypothesis**)
- If I climb, I can collect the paint (**prediction**)
- I climb the mountain (**experiment**)
- I can't collect the paint (**observation**)
- The sky is painted blue but is very high (**revised hypothesis**)
- If I fly a plane, I can collect blue

Inconsistent results? Revise the hypothesis

Strengths of The Scientific Method: Self Correction by Peer Review

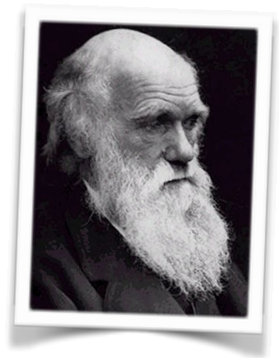
- People have deliberately faked the results of experiments for personal gain
  - The scientific method almost always uncovers this
- People have accidentally proposed 'incorrect' ideas
  - The scientific method almost always corrects this
- People have produced revolutionary ideas that went against the prevailing view
  - The scientific method almost always supports a correct but revolutionary idea, although it may take a long time
- Some discoveries are made by chance or luck
  - Some discoveries are made by chance but the scientific method is almost always employed to understand the discovery

Strengths of The Scientific Method: Self Correction by Peer Review

- Andrew Wakefield
  - Deliberately faked results on the link between MMR vaccin and autism but was discovered by others and discredited

- Fleischmann and Pons
  - 'Discovered cold fusion', a benchtop nuclear reaction, but accidentally made experimental mistakes and later work b others couldn't repeat it

- Charles Darwin
  - Published 'Origin of the Species' to much scientific and pubic controversy yet evolution is now a cornerstone of biology



- Hans von Pechmann
  - Accidentally made the first plastic (polyethylene) but many

Scientific Theories and Facts

- A **scientific theory** is a general statement, supported by all evidence, that provides some conceptual explanation of how a phenomenon happens
  - The theory of relativity states that the laws of physics are the same for both stationary and moving observers
  - The germ theory of disease states that some illnesses are caused by microscopic organisms
- A **scientific fact** is an objective, verifiable observation
  - The earth is spherical
  - Viruses and bacteria are microscopic organisms
- Note that a theory provides an explanation of

Scientific Laws

- A **scientific law** (or principle or rule) is a concise, general summary of related observations or facts
  - Laws are less general than theories (they might not always apply)
  - Laws offer no concepts or explanations
- Laws in chemistry are often expressed in terms of mathematical expressions
  - Boyle's law, usually written $V = k \cdot T/P$, relates three facts about the volume, pressure and temperature of gases
  - The kinetic theory of gases explains why Boyle's law is usually true and predicts when it might not be true
- Theories incorporate facts and laws

Test Yourself: Scientific Fact, Law Or Theory?

- Chemistry is difficult to learn because it involves memorization, mathematics, concepts and problem solving
  - Theory - an explanation why chemistry is difficult
- Flames emit light, flicker and are hot
  - Facts - no explanation as to why
- Force = mass × acceleration
  - Law - based on multiple observable facts but no explanation as to how or why
- Substances are colorless because they do not absorb light

Misconceptions About Theories, Laws And Facts

- A **scientific theory** is not an 'unproven' law
  - A theory does not become a law
- When we say "I have a theory…" we usually mean "I have a hypothesis…"
- It is impossible to 'prove' a theory
  - A weight of evidence only increases confidence that the theory is correct but it may be be changed in light of new evidence at any time
- A law can still be useful even if it does not hold true all the time
  - Newton's laws of motion govern the movement of objects under the influence of gravity but fail for very small objects

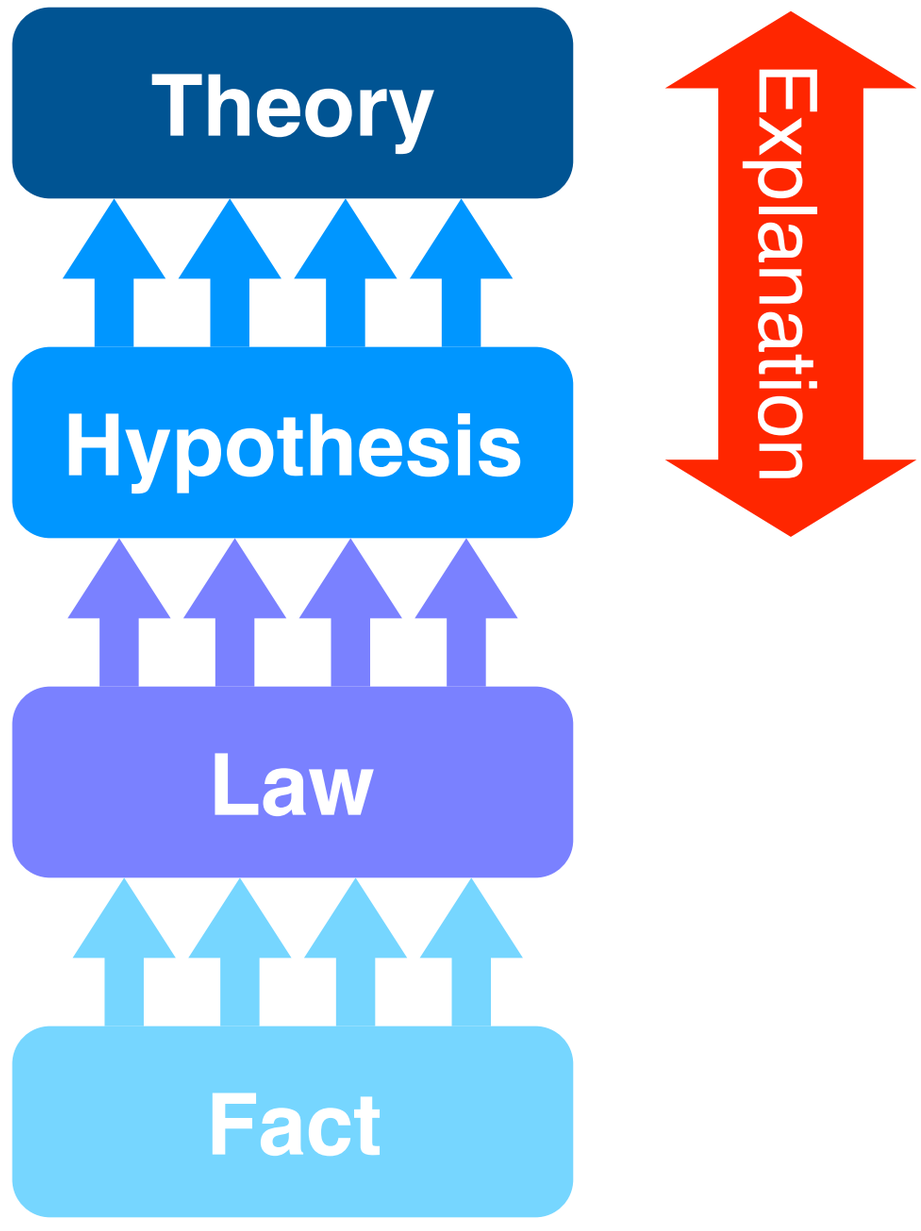
Summary: Theory, Hypothesis, Law, Fact

Most complete explanation; much tested; no contrary evidence

“Educated guess”; one possible explanation; not fully tested

Collects related facts together; much tested; generally true

Single observation; specific circumstances



Fringe Ideas or Pseudoscience

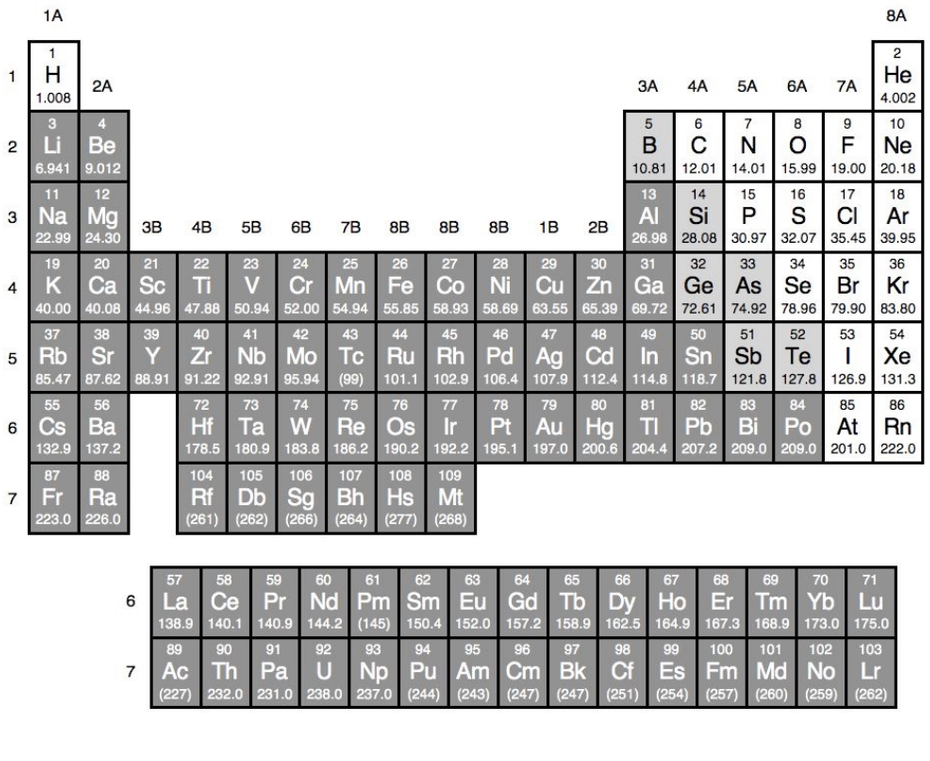
- **Pseudoscience** (alternative/junk science) claims to be scientific but does not follow accepted methods
- Science uses **control experiments** to provide a reference against which results can be compared
  - Smoking causes lung cancer; control experiment is a measure of lung cancer in non-smoking population
- **Experimental variables** are the aspects of the experiment changed from trial to trial
  - Smoking causes lung cancer; a scientist might change amount of nicotine in the tobacco or sex of the subject
- Only one experimental variable is changed at a time
  - Smoking causes lung cancer; was it the change in nicotine or the sex of the subject that caused an effect?

Examples of Pseudoscience

- Extra sensory perception
- Chi energy
- Astrology
- Structurally altered, ionized, magnetized or oxygenated drinking water
- Magnetic therapy
- Electronic pest deterrents
- Psychic powers
- Many homeopathic cures
- Creationism / intelligent

Science	Pseudoscience
Primary goal is a more complete understanding	Primary goal is cultural, religious or commercial
Intense research with constant expansion	Little research or expansion since inception
Inconsistencies generate debate and research	Inconsistencies are suppressed or denigrated
Theories built or discredited on reproducible experiments and results	Ideas not testable or reproducible and based on beliefs or preconceptions
Explanations in unambiguous and precise scientific language	Explanations in vague and ambiguous terms using scientific-type language

1.4 Pattern Recognition



- Science in general and chemistry in particular attempts to organize phenomena by patterns or trends
  - The periodic table is arranged to highlight such trends
- Trends allow scientists to make predictions about things they have never encountered
  - If burning gasoline and oil produces heat, it is reasonable to

1.5 Representing Quantitative Information as Equations

- Scientific laws often can be written as **equations**
  - An equation is a shorthand way of expressing a law
  - It contains <u>all</u> the relevant information
  - Symbols (**variables**) are used to represent real things
- For example, a scientific law (the ideal gas law) states that the pressure and volume inside a balloon depends on the amount of gas inside and temperature

$$P \cdot V = n \cdot R \cdot T$$

- where P is pressure, V is volume, n is the amount of gas, R is a constant and T is temperature

Representing Quantitative Information - Equations

- The equation can be manipulated to show the relations between variables

$$\frac{P \cdot V}{V} = \frac{n \cdot R \cdot T}{V}$$

$$P = \frac{n \cdot R}{V} \cdot T$$

- Since (n·R / V) is constant if V is fixed

$$P = \text{constant} \cdot T$$

Representing Quantitative Information - Equations

$$P = \text{constant} \cdot T$$

- What does this equation mean?
- Pressure is **directly proportional** to temperature
  - Doubling the temperature will double the pressure
  - Increasing the temperature by 7% will increase the pressure by 7%
- We can test this relationship by measuring the pressure in a container of fixed volume and amount of gas
  - For example, measure pressure in a car tire on a warm and cold day

Representing Quantitative Information - Equations

- If we do an experiment where we purposely vary the temperature, we are changing the **independent variable**
- The pressure changes in response and so is called the **dependent variable**
- We can also show this data as a graph

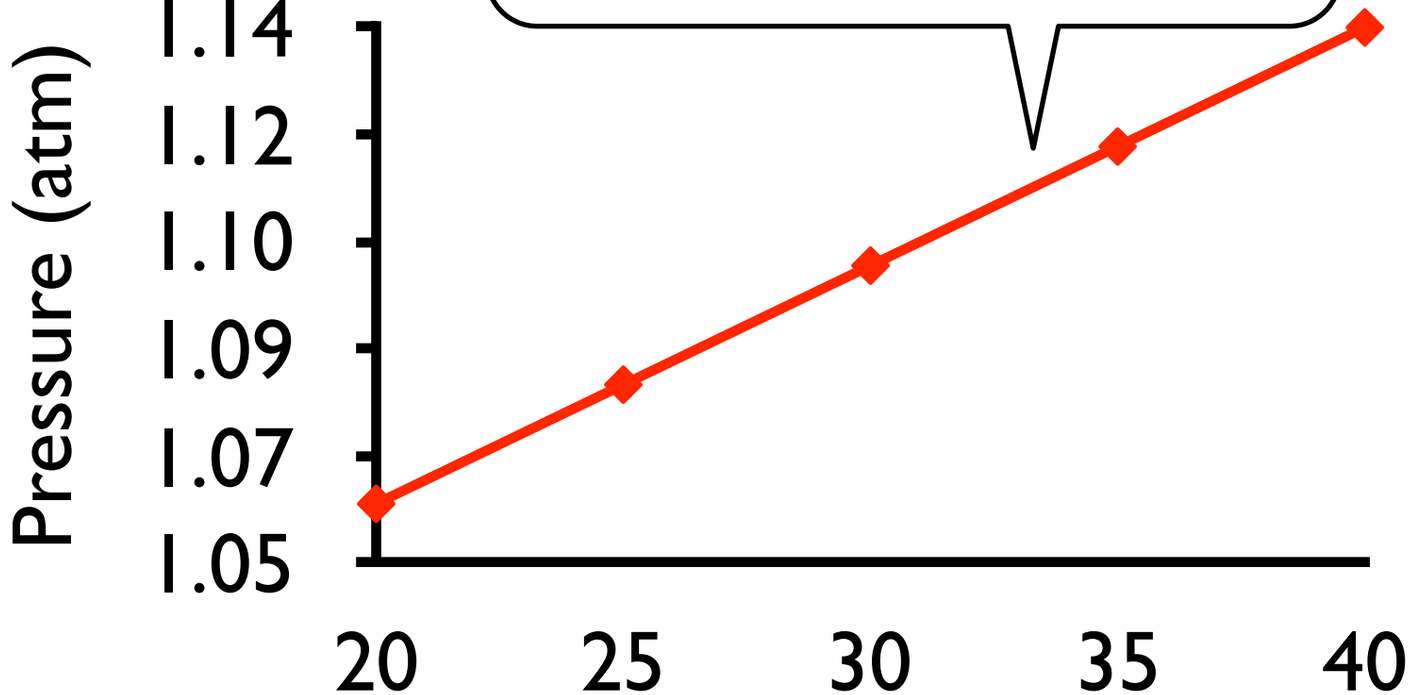
Temperature (°C)	Pressure (atm)
20	1.06
25	1.08
30	1.1
35	1.12
40	1.14

Representing Quantitative Information - Graphs

This is a graph of pressure (y) versus temperature (x)

A straight line proves pressure is directly proportional to temperature

- For **directly proportional**, one variable <u>increases</u> as the other <u>increases</u>



Independent variable on x axis

Representing Quantitative Information - Equations

- If we divide by V we get a different relation

$$P \cdot V = n \cdot R \cdot T$$

$$P = \frac{n \cdot R \cdot T}{V} = n \cdot R \cdot T \cdot \frac{1}{V}$$

- Since (n·R·T) is constant if T is fixed

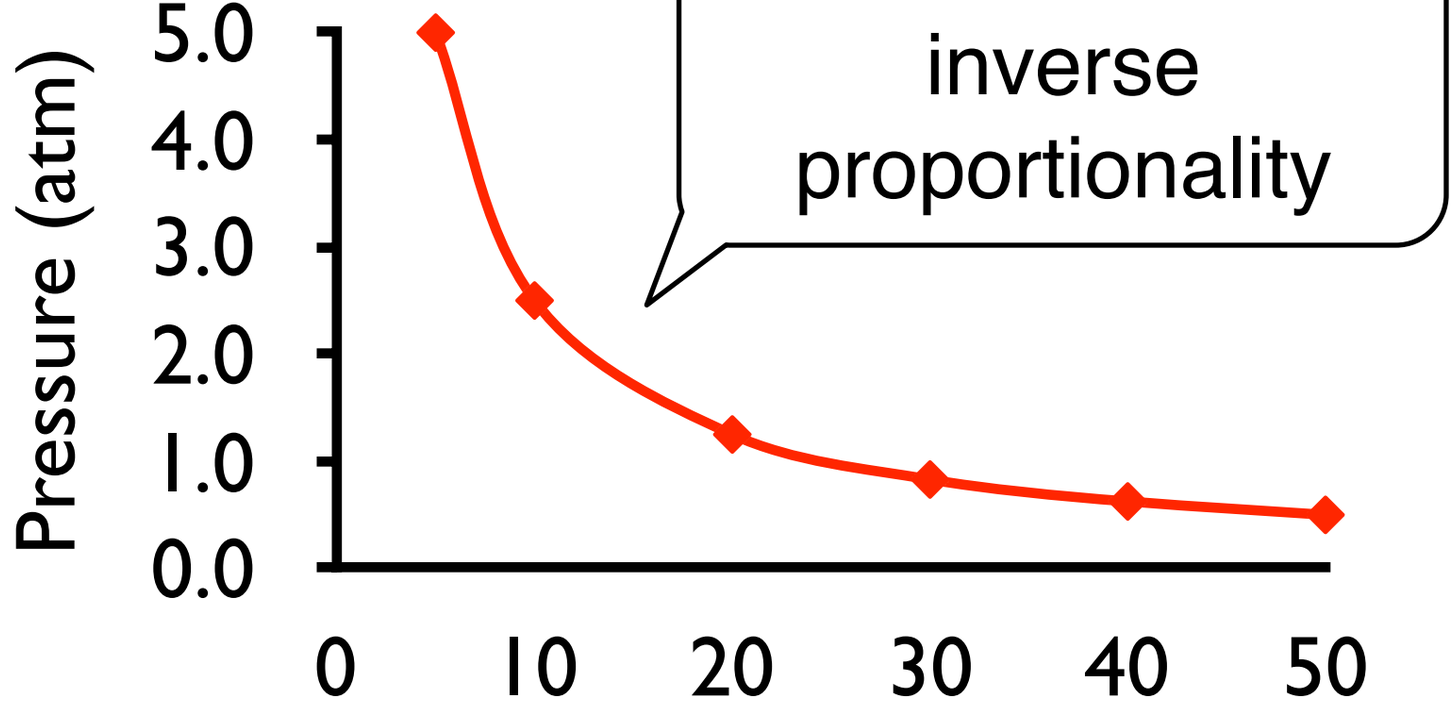
$$P = \frac{\text{constant}}{V}$$

- Pressure is **inversely proportional** to volume

Representing Quantitative Information - Graphs

This is a graph of pressure (y) versus volume (x)

- For **inversely proportional**, one variable <u>increases</u> as the other <u>decreases</u>



A curve (hyperbole) is characteristic of inverse proportionality

The graph is labeled with axis variable <u>and</u> units

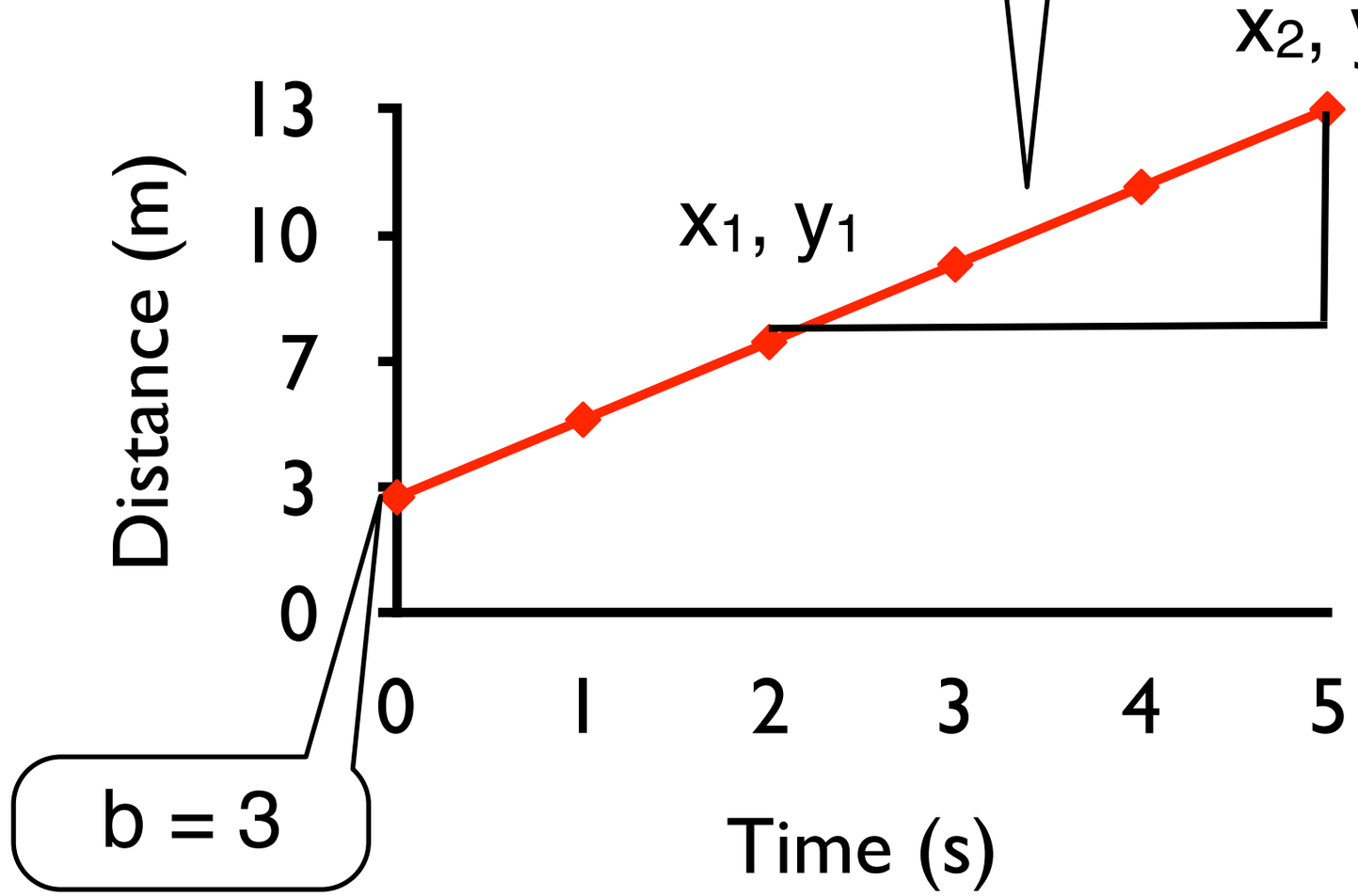
Straight Line Graphs

- The **equation of a straight line** is

$$y = m \cdot x + b$$

- where y is the dependent variable, m is the **slope**, x is the independent variable and b is the **y-axis intercept**

$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{13\,m - 7\,m}{5\,s - 2\,s} = 2\,m/s$$



Test Yourself: Straight Line Graphs

Q What is the pressure inside the container when the temperature is 200 °C?

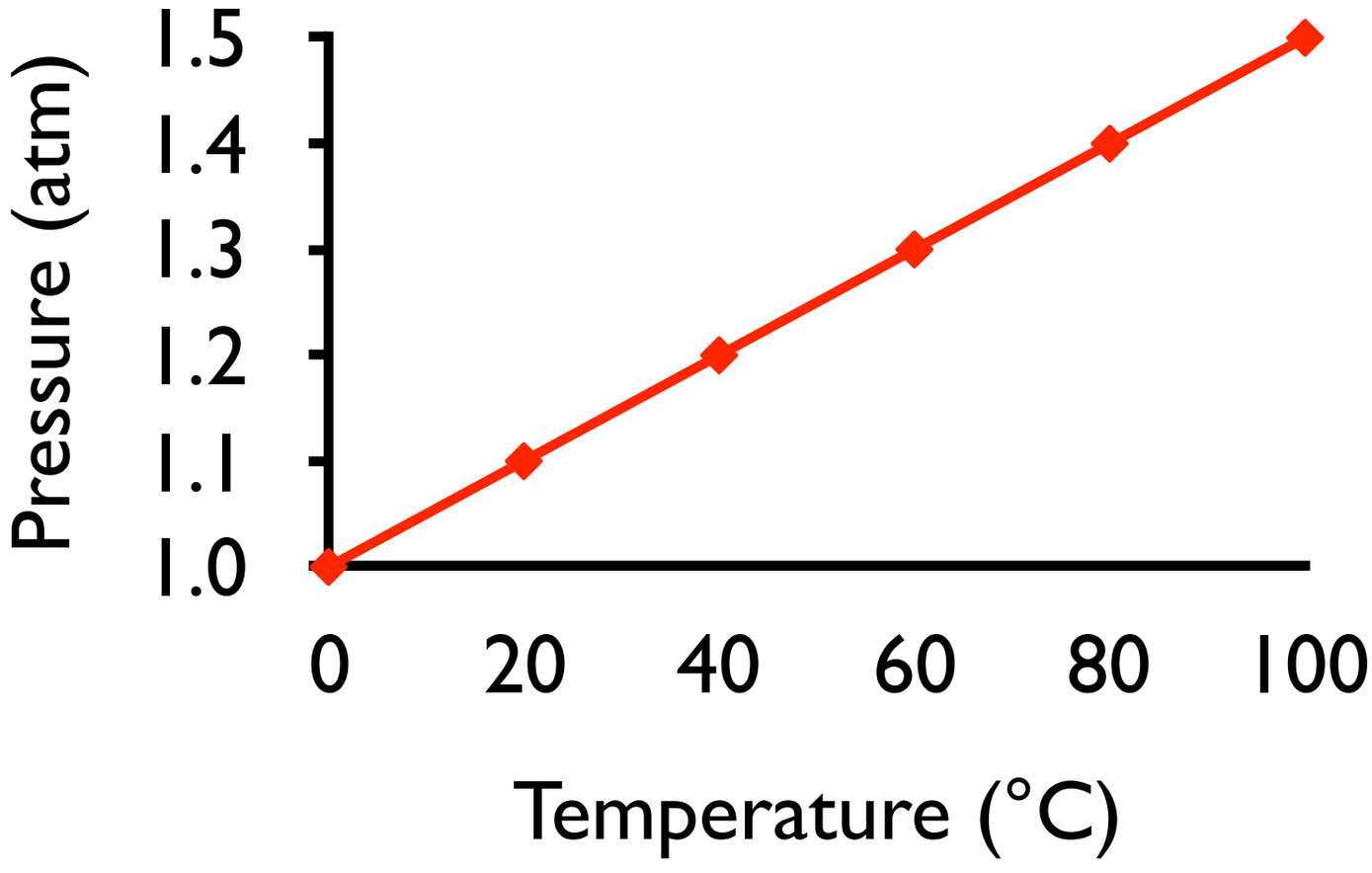
A Find the equation for the line

$$y = m \cdot x + b$$

$$P = m \cdot T + b$$

$b = 1.0$ atm

$m = 0.005$ atm/°C



$P = (0.005 \text{ atm/°C} \times 200 \text{ °C}) + 1.0 \text{ atm} = 2.0 \text{ atm}$

Review: Learning Objectives

- Identify the elements and apply the scientific method (Section 1.2; Exercises 1-10)
- Distinguish between science and pseudoscience (Section 1.3; Exercises 13, 17)
- Plan a scientific experiment (Section 1.1-1.3; Exercises 11, 12, 17)
- Identify quantitative relationships between two quantities (Section 1.5; Exercise 14)
- Graph quantitative data (Section 1.5; Exercise 15)
- Interpret straight line graphs (Section 1.5; Exercise 16)