



CH-110 Advanced General Chemistry I

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Fundamentals A: Matter and Energy

Please review yourself.

Important definitions

- **Matter:** anything that has mass and takes up space
- **Substance:** single, pure form of matter
- States of matter:
 - A **solid** is a form of matter that retains its shape and does not flow.
 - A **liquid** is a form of matter that has a well-defined surface; it takes the shape of the part of the container it occupies.
 - A **gas** is a fluid form of matter that fills any vessel containing it.
- **Vapor** denotes the gaseous form of a substance that is normally a liquid or solid. For example, water exists as a solid (ice), liquid, and as vapor (steam).

Physical vs. chemical properties

- **A physical property** of a substance is a characteristic that can be observed or measured without changing the identity of a substance.
- *E.g. mass, temperature, melting point, hardness, color, state of matter, and density.*
- **A chemical property** refers to the ability of a substance to be changed into another substance.
- *E.g. a chemical property of hydrogen gas (H_2) is that it reacts with oxygen (O_2) to produce water (H_2O). Oxidation states, reactivity with acids or bases, electronegativity, radioactivity.*

Symbols and units

| SI Base Units | | | |
|---------------------------|------------------------|-----------|--------|
| Base quantity | | Base unit | |
| Name | Typical symbol | Name | Symbol |
| time | t | second | s |
| length | $l, x, r, \text{etc.}$ | meter | m |
| mass | m | kilogram | kg |
| electric current | I, i | ampere | A |
| thermodynamic temperature | T | kelvin | K |
| amount of substance | n | mole | mol |
| luminous intensity | I_v | candela | cd |

Source: NIST Special Publication 330:2019, Table 2.

Significant figures

- The number of significant figures in a numerical value is the number of digits that can be **justified by data**.
- When reporting the results of **multiplications and divisions**, identify the number of digits in the least precise value and retain that number of digits in the answer.
- When reporting the results of **additions and subtractions**, identify the quantity with the least number of digits following the decimal point and retain that number of digits in the answer.

Accuracy and precision

- **Precision** of a measurement is an indication of how close repeated measurements are to each other.
- **Accuracy** of a series of measurements is the closeness of their average value to the true value.

To remember:

Precision is how **Packed** the measurements are together (close to each other).

Accuracy is how accurate the measurements are to the **Actual value** (close to the true value).

Which case is precise but inaccurate?

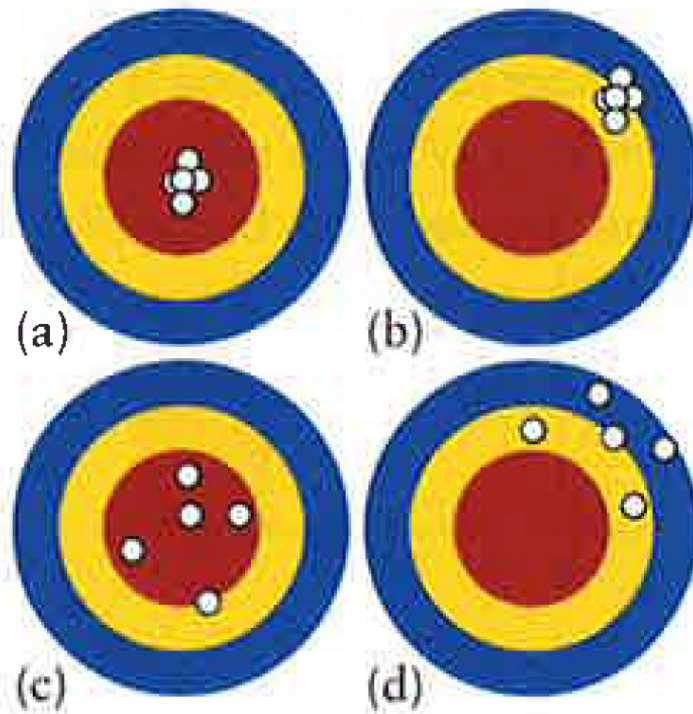
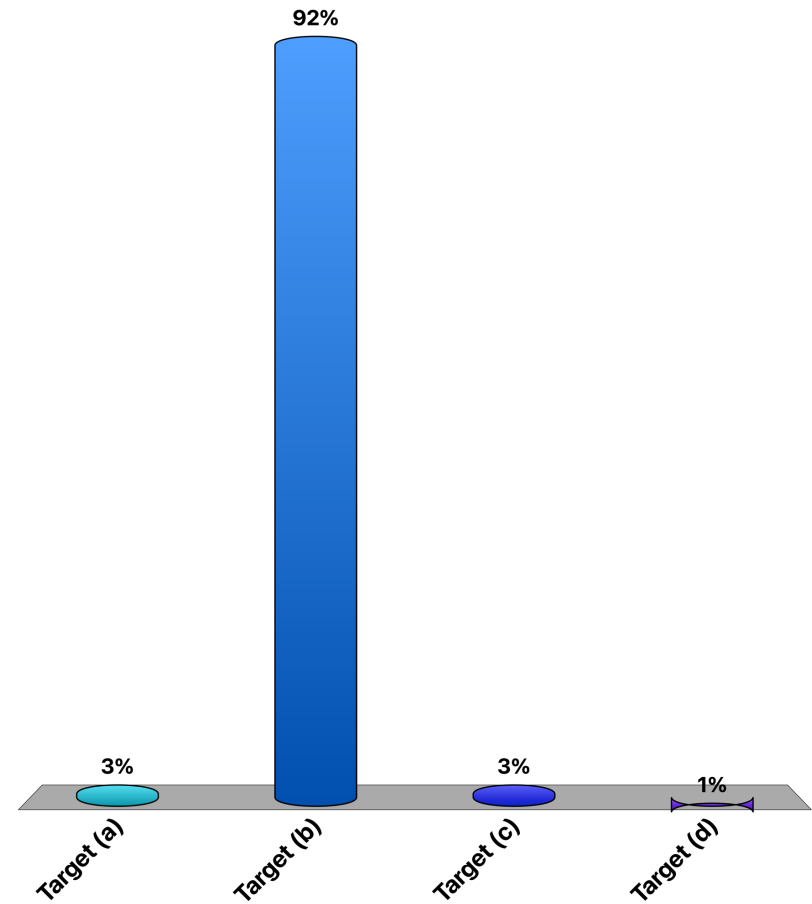


Figure A.3



Systematic vs. random error

- A **systematic error** is present in every one of a series of repeated measurements. Same sign and magnitude. E.g. lab scale that is not properly calibrated.
- A **random error** varies in both sign and magnitude and can average to zero over a series of measurements.

Speed vs. velocity

Speed, v (m/s): it describes how fast an object is moving but does not include any information about direction (**scalar** quantity)

Velocity: closely related to speed: rate and DIRECTION (**vector** quantity)

For example: A particle moving in a circle at a constant speed has a constantly changing velocity.

Acceleration, a : rate of change of velocity

For example: A particle is moving in a straight line at a constant speed is not accelerating (speed plus direction same).

BUT: a particle moving at a constant speed in a curved path accelerates because although its speed is constant, its velocity is changing (this is called **centripetal acceleration**).

Force

Force is an influence that changes motion of an object.

E.g. you exert force to open door or hit a ball with a baseball bat.

Newton's second law of motion: When an object experiences a force, it is accelerated in proportion to the force it experiences.

$$a = \frac{F}{m}$$

m : mass of body

Energy

Work is the process of moving an object against an opposing force:

$$\text{Work done} = \text{force} \times \text{distance}$$

Units: $1 \text{ Nm} = 1 \text{ J}$ (equals the work of one human heart beat)

Energy: capacity to do work

e.g. energy is needed to do the work of raising a weight (book) to a given height or forcing an electric current through a circuit.

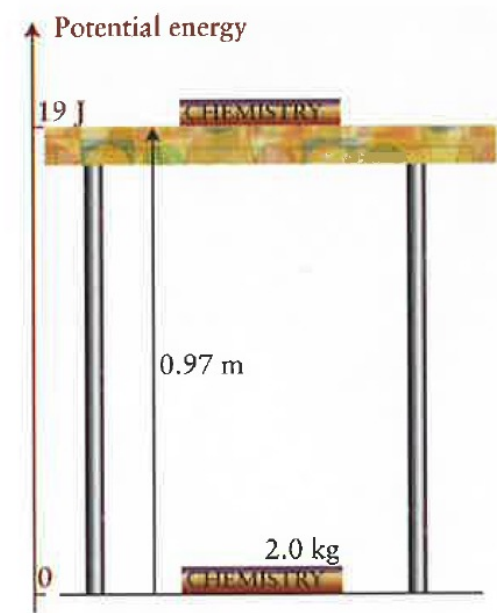


Figure A.5

Energy in chemistry

1. Kinetic energy, E_K , is the energy that a body possesses due to its motion. For a body of mass m traveling at a speed v , the kinetic energy is

$$E_k = \frac{1}{2} m v^2$$

2. Potential energy, E_P , of an object is the energy that it possesses on account of its position in a field of force. No single formula because E_P depends on the nature of the force it experiences. Two simple cases:

1) A body of mass m at a height h above the surface of the Earth has **a gravitational potential energy**:

$$E_p = mgh$$

with g , acceleration of free fall ("acceleration of gravity") of 9.81 m s^{-2}

Energy in chemistry

2. Potential energy

2) **Coulomb potential energy** of a particle Q_1 at a distance r from another particle of charge Q_2 is proportional to the two charges and inversely proportional to the distance r between them:

$$E_P = \frac{Q_1 Q_2}{4\pi\epsilon_0 r}$$

ϵ_0 : electric constant ($8.854 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$)

Figure A.7: Coulomb potential energy of two opposite charges (red and green sphere), potential energy decreases as the charges approach each other.

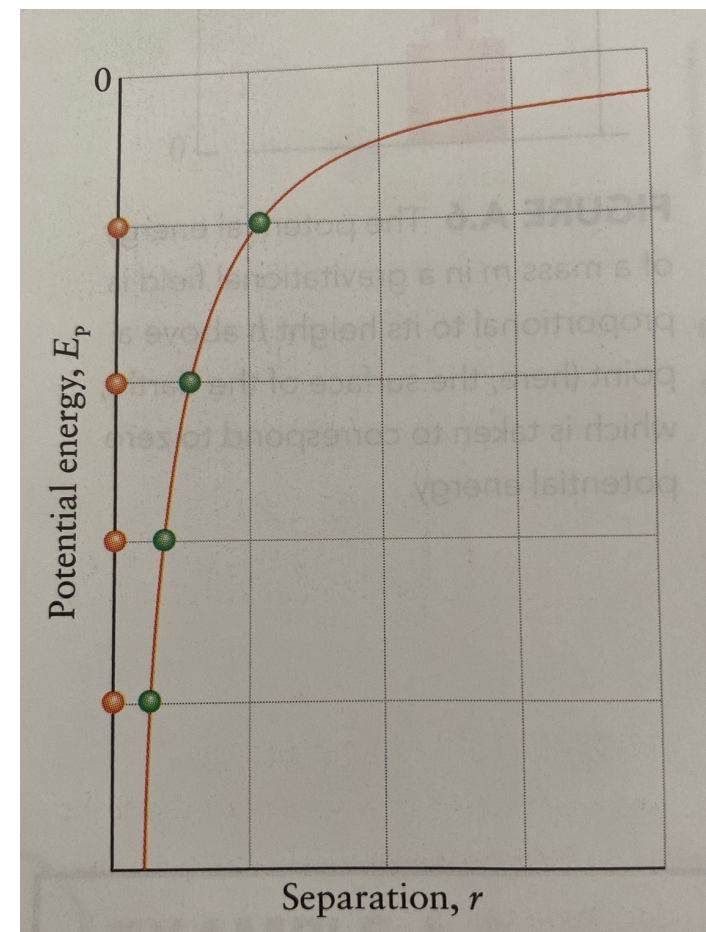


Figure A.7

Energy in chemistry

3. The electromagnetic energy is the energy of the electromagnetic field, such as the energy carried through space by radio waves, light waves, and X-rays.

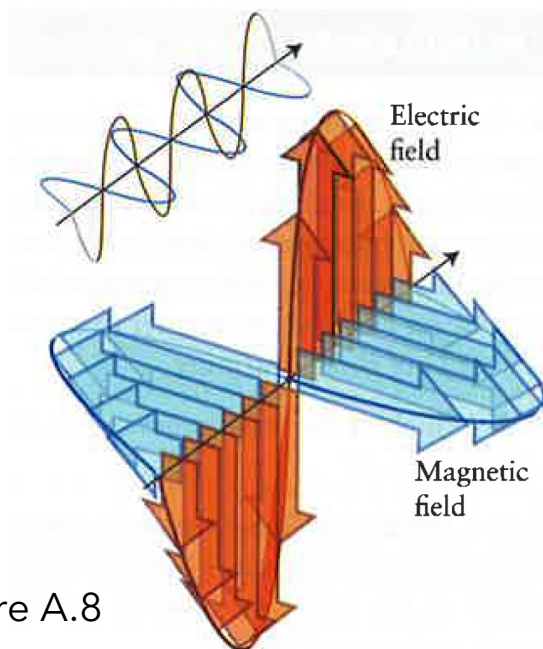


Figure A.8

Electromagnetic field is generated by **acceleration of charged particles**.

The field consists of **an oscillating electric field** and **oscillating magnetic field**.

The electric field affects charged particles whether they are moving or not.

The magnetic field only affects *moving* charged particles.

More in Topic 1A.

Energy in chemistry

The total energy, E , of a particle is the sum of its kinetic and potential energies:

$$E = E_k + E_p$$

E is **conserved** (constant) for a given, isolated system.

What happens when the ball hits the earth?

Ball is no longer isolated.

Energy dissipates as thermal motion.

Total energy of earth has increased by exactly the same amount as that lost by the ball.

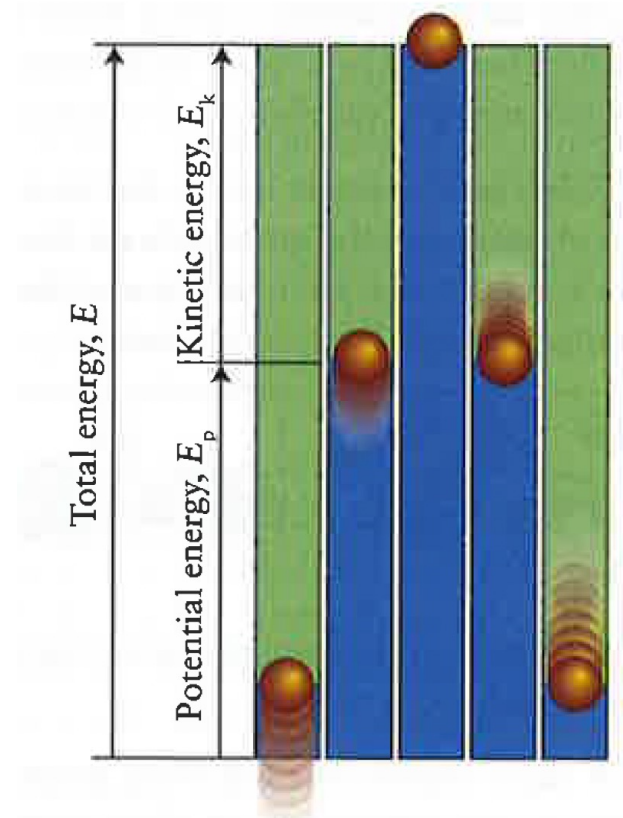
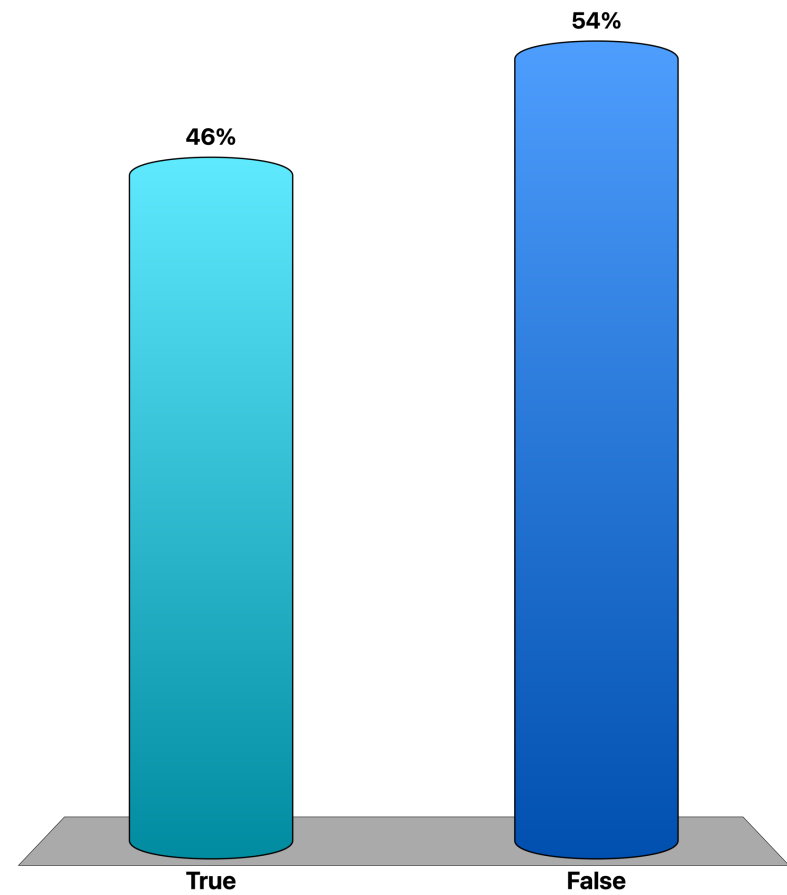


Figure A.9

Work and energy have the same units.

- A. True
- B. False



True.

Work and **energy** both have the same units, which are **joules (J)** in the International System of Units (SI).

Work is defined as the transfer of energy when a force is applied over a distance, and it's calculated using the formula:

$$\text{Work} = \text{Force} \times \text{Distance}$$

Since force is measured in **newtons (N)** and distance in **meters (m)**, the unit of work becomes:

$$1 \text{ joule (J)} = 1 \text{ newton-meter} = 1 \text{ N}\cdot\text{m}$$

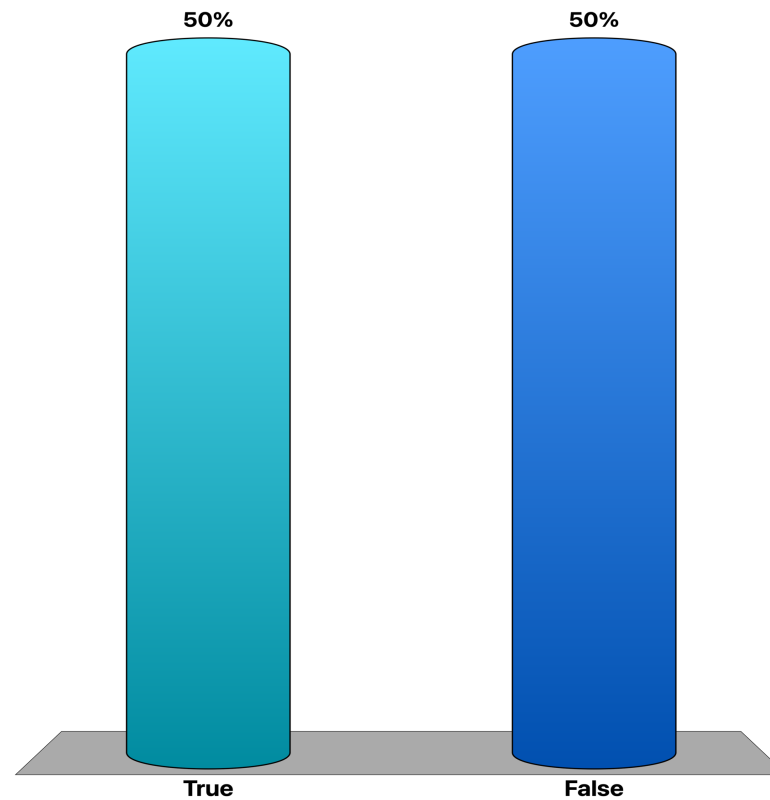
Energy (such as kinetic energy, potential energy, etc.) is also measured in **joules (J)**. For example, the formula for gravitational potential energy is:

Potential Energy = mgh where mass is in kilograms (kg), gravity is in meters per second squared (m/s^2), and height is in meters (m), resulting in joules.

Thus, both work and energy are measured in **joules**, which is a way of quantifying the amount of energy transferred or the energy stored in a system.

According to Newton's second law of motion, an object will always accelerate, even if no force is applied to it.

- A. True
- B. False



False.

- According to **Newton's first law of motion** (the law of inertia), an object will remain at rest or in uniform motion (constant velocity) unless acted upon by an external force. In other words, if **no force** is applied to an object, it will not accelerate—it will either stay at rest or continue moving in a straight line at constant speed.
- **Newton's second law** further clarifies this with the equation:
- $F=ma$
- **F** is the net force,
- **m** is the mass,
- **a** is the acceleration.
- If **no force** is applied, then $F=$ and since m is constant, this means $a=0$, so the object will not accelerate.
- Thus, an object **only accelerates when a net force** is applied to it. If there is no force, there is no change in motion (no acceleration).

The skills you have mastered are the ability to

- ❑ Identify properties as physical or chemical.
- ❑ Convert between units.
- ❑ Calculate the kinetic energy of an object.
- ❑ Calculate the gravitational potential energy of an object.
- ❑ Express how the Coulomb potential energy depends on electric charge.

Summary: Work is motion against an opposing force. Energy is the capacity to do work. Kinetic energy results from motion, potential energy from position. An electromagnetic field carries energy through space.